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# Dundee Discussion Papers in Economics

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Unionisation,  
International Integration and Selection

Catia Montagna & Antonella Nocco

# Unionisation, International Integration and Selection\*

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## Abstract

We study how unionisation affects competitive selection between heterogeneous firms when wage negotiations can occur at the firm or at the profit-centre level. With productivity specific wages, an increase in union power has: (i) a selection-softening; (ii) a counter-competitive; (iii) a wage-inequality; and (iv) a variety effect. In a two-country asymmetric setting, stronger unions soften competition for domestic firms and toughen it for exporters. With profit-centre bargaining, we show how trade liberalisation can affect wage inequality among identical workers both across firms (via its effects on competitive selection) and within firms (via wage discrimination across destination markets).

**Keywords:** firm selection, unionisation, wage inequality, trade liberalisation

**J.E.L. Classification:** F12, F16, R13, J51

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# 1 Introduction

This paper aims to shed light on how labour market unionisation affects the competitive selection effects of international trade and wage dispersion in the presence of firm heterogeneity and inter-country asymmetries. Specifically, we extend the monopolistic competition model developed by Melitz and Ottaviano [27] to allow for firm-specific unions.

In recent years, new good quality firm-level data has drawn attention to the existence of substantial intra-industry heterogeneity in performance across firms and to the role of competitive selection in determining the export performance of countries. For instance, a recent Bruegel and CEPR report [24] documents how the international performance of European countries is driven by a relatively small number of firms which are more productive and larger than others, but that also pay higher wages.

Consistent with this evidence, an emerging body of empirical literature finds that the link between international trade and wage dispersion works through the wage differentials between exporters and non-exporters,<sup>1</sup> suggesting that firm heterogeneity and competitive selection processes may be a key channel through which trade liberalisation contributes to the increasing wage inequality observed across countries – particularly in light of the fact that a large proportion of this inequality occurs in most countries within-groups and not only between groups of workers with different observable characteristics (such as skills and education).<sup>2</sup> The effects of international trade on the equilibrium size-distribution and export status of firms, however, also appear to be influenced by other factors such as changes in the market power of firms (e.g. Wälde and Weiß, [38]), or labour market liberalisation (e.g. Coşar *et al*, [8]).

A key stylised fact that motivates our analysis in this paper is that, across the OECD as a whole, increases in wage dispersion have been paralleled by a widespread tendency towards a reduction in the degree of centralisation of collective wage bargaining. As highlighted in a number of OECD reports ([31], [32], [33]), even in countries with traditionally centralised industrial relation systems such as Germany and Italy, the importance of industry level negotiations has diminished and the prominence of firm-level and plant-level agreements has increased since at least the mid 1990s.<sup>3</sup> This trend is particularly marked in the manufacturing sector, which has traditionally been more centralised than others. As argued by Driffill [11], the decentralisation of wage setting reflects

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<sup>1</sup>See for instance Menezes-Filho *et al* [28] and Schank *et al* [35] and references therein.

<sup>2</sup>See among others: Autor *et al* [4], McCall [25], Barth and Lucifora [5], Goos and Manning [16] and Dustmann *et al* [12].

<sup>3</sup>In Germany, plant-level agreements have proliferated since the early 1990s via the enactment of *opening clauses* that authorise companies to opt-out of national negotiations (Jürgens, [21]). In Italy, a progressive decentralisation of bargaining to the company level that began in the early 1990s culminated in the recent (January 2011) agreement at the FIAT Mirafiori plant which is widely recognised as paving the way to a widespread move towards sub-firm level agreements outside industry wide frameworks. In the UK, the tendency towards bargaining decentralisation has been noted since the early 1980s. Company or plant level bargaining is characteristic of Canada, Japan, Korea, the United States, New Zealand, and in Mexico (see e.g. Tuman, [36]).

a reduction of union power resulting from the combined effects of a shrinking share of employment in manufacturing and an increasing competitive pressure due to international economic integration. Indeed, the adoption of highly decentralised bargaining practices has typically been motivated by the argument that in the interest of international competitiveness wage settlements ought to reflect variations in productivity and profitability across both firms and profit-centres (or divisions) within individual firms – which industry level agreements fail to recognize.

To capture these stylized facts, we develop a framework in which the competitive pressure (and hence markup) is both firm-specific and market-specific, and wages are set via a bargaining process between unions and firms which can occur at the firm or at the sub-firm (i.e. at the *profit-centre*) level. We then examine how the interplay between unionization and international trade affects industry performance and selection within environments characterized by different degrees of integration between countries as well as by other inter-country asymmetries.

Recent theoretical developments have provided micro-foundations for the existence of inter-firm differences in productivity and a considerable body of literature has focussed on their effects on export performance.<sup>4</sup> In comparison, relatively little attention has been devoted to the interaction between firms' selection and labour markets and most papers that do so do not focus on the role of unions as a source of labour market imperfections. Within an efficiency wage model, Davis and Harrigan [9] find that wages differ between firms as a result of their different monitoring technologies. A fair-wage effort mechanism where wages depend on productivities is used by Egger and Kreickemeier [14] who find that more integration increases wage inequality.<sup>5</sup> Helpman and Itzhak [18] study the effects of hiring and firing rigidities on trade and unemployment and find that, unless a non-linear hiring function is assumed, wages are the same across firms. Wage dispersion emerges instead in Helpman *et al* [19], but as a result of heterogeneity of workers in some unobservable ability. Felbermayr, Prat and Schmerer [15], in a model with search frictions with individual or collective efficient wage bargaining, find that firms with different productivities pay similar wages regardless of the bargaining environment. Unionization is considered, within a different context from ours that focuses on multinational production, by Eckel and Egger [13] who find wages to be the same for all firms, with a wage premium paid by exporters. Furthermore, with the exception of Helpman and Itzhak [18] and Helpman *et al* [19] who allow for inter-country asymmetries in the degree of labour market frictions, all the above mentioned works differ from our model in that they assume fully symmetric countries.

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<sup>4</sup>Montagna [29] studies the effects of trade liberalization on firms' selection in the presence of inter-country differences in firms' productivity distributions. Melitz [26] introduces a fixed export cost in the presence of uncertainty about post-entry efficiency and shows how only more productive firms self-select into an export status. For recent reviews of the literature, see Helpman [17] and Redding [34].

<sup>5</sup>Amiti and Davis [2] adopt a similar framework and test its predictions using highly detailed Indonesian manufacturing census data.

A conclusion that can be drawn from these contributions is that the emergence of inter-firm wage dispersion, whereby more efficient firms pay higher wages, crucially rests on the existence of a rent-sharing mechanism between workers and firms. Our choice to focus on unionisation, rather than on other forms of labour market imperfection, is motivated by the key role that unions continue to play, despite a decline in union membership, in most industrial economies (see, e.g., Visser [37]).

The results of our paper enrich the literature in this area. With endogenous markups, bargaining between heterogeneous firms and firm-specific unions implies that wages will differ between firms – with more efficient firms paying higher wages. This is consistent with the results obtained by Egger and Kreickemeier [14] and others. However, in our model, the rent extracted by a union does not only depend on the productivity of the firm but also on its market power – which is firm specific. In particular, a firm’s price elasticity of demand decreases in its productivity. Therefore, more efficient firms enjoy a stronger monopoly position in the industry and offer a higher potential for rent extraction to their union. Due to market segmentation, however, the monopoly power of firms is also market specific – with an exporting firm thus having two independent *profit-centres* associated with its domestic and export sales respectively. In this context, we show how a decentralisation of bargaining at the sub-firm (i.e. profit-centre) level alters rent-sharing incentives and outcomes and results in *wage discrimination* across the different activities of the firm, as unions moderate their export wage requests in order to aid their firm’s access to foreign markets. A key implications of our analysis, therefore, is that – as the wage setting process shifts to the sub-firm level – trade liberalisation can affect wage inequality even among identical workers within an industry along two dimensions: *across firms* (via its effects on competitive selection) and *within firms* (via wage discrimination across destination markets).<sup>6</sup> As argued by Egger and Kreickemeier [14], to the extent that firm-heterogeneity in productivity leads to wage dispersion within industries, workers are not indifferent as to which firm they are employed by. Our analysis further suggests that – as sub-firm level negotiations gain in importance worldwide – workers may also increasingly not be indifferent as to which operation of an efficient firm they will work in.

Since, for a given bargaining power, a union’s rent extraction ability is higher the higher is the productivity of the firm, an increase in union power in one country will translate in relatively larger wage demand increases in relatively more efficient firms – i.e. stronger unions will hurt (via higher wages) more efficient firms relatively more than less efficient ones. This will generate a *counter-competitive effect*, amounting to a reduction in the average productivity of the industry, and will also act as a *competition-softening* device for domestic firms and as a *competition-toughening* device for exporting firms (by increasing the minimum level of productivity required to export, as stronger unions moderate wage demands less). Via its effects on competition and selection, an increase in

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<sup>6</sup>Wälde and Weiß [38] obtain within-firm wage inequality as a result of unobservable individual characteristics.

union power may also have a *pro-variety effect* that, by increasing the number of firms in the economy, will raise welfare despite the lower average productivity in the industry. We show how, in this framework, a trade liberalisation that facilitates access to a foreign market – by reducing the minimum level of productivity required to export and thus softening the need for wage moderation to protect firms’ international competitiveness – will reduce within-firm wage dispersion. The opposite will happen if trade liberalisation implies that the domestic market becomes more accessible to foreign firms.

The rest of the paper is organized as follows. Section 2 sets out a closed economy version of the model and derives its long run equilibrium properties. Section 3 extends the framework to a two-country world. Section 4 concludes the paper and draws out some of the key testable hypotheses that emerge from the analysis.

## 2 Autarky

We consider an economy populated by  $L$  identical households supplying labour services to a competitive industry, that produces a homogeneous good, and to a monopolistically competitive industry, that produces a horizontally differentiated good. Firms in the monopolistic sector are heterogeneous in their productivity and discover their level of technical efficiency only after having made a costly and irreversible investment prior to entry into the industry. As is standard in the monopolistic competition literature, we assume there to be a continuum of potential firms in this sector, each sufficiently small so as to ignore the impact of its actions on the behaviour of its competitors. Thus, while enjoying – by virtue of product differentiation – some monopoly power, firms do not strategically interact with each other. In terms of preferences and technologies, the model is based on the framework developed by Melitz and Ottaviano [27]. The key difference with their model is that workers in the monopolistic sector are organized in firm-specific unions which bargain with firms over the wage.

### 2.1 Preferences

Consumer preferences, defined over a continuum of varieties (indexed by  $i \in \Omega$ ) of a horizontally differentiated good and a homogeneous good, are described by the following quadratic quasi-linear utility function:

$$U(q_0^\zeta; q^\zeta(i), i \in \Omega) = q_0^\zeta + \alpha \int_{i \in \Omega} q^\zeta(i) di - \frac{1}{2} \delta \int_{i \in \Omega} q^\zeta(i)^2 di - \frac{1}{2} \eta \left( \int_{i \in \Omega} q^\zeta(i) di \right)^2, \quad (1)$$

where  $q^\zeta(i)$  is a typical household  $\zeta$ ’s consumption of variety  $i$  of the differentiated good and  $q_0^\zeta$  is its consumption of the homogeneous good;  $\alpha$ ,  $\delta$  and  $\eta$  are positive preference parameters. Specifically:  $\delta$  captures the degree of consumers’ bias towards product differentiation (i.e. towards a dispersed consumption of varieties); both  $\alpha$  and  $\eta$  capture the intensity of preferences for the

differentiated good with respect to the homogeneous good (which increases in  $\alpha$  and decreases in  $\eta$ ); a higher  $\eta$  also reflects a higher degree of substitutability between varieties.

It will prove convenient to use the homogenous good as the numeraire and set its price at unity, i.e.  $p_0 = 1$ . Then, denoting with  $\tilde{\Omega} \subset \Omega$  the subset of varieties that are consumed, the budget constraint of a typical household will be given by:

$$\int_{i \in \tilde{\Omega}} p(i) q^\zeta(i) di + q_0^\zeta = I_\zeta + \bar{q}_0, \quad (2)$$

where  $p(i)$  is the price of variety  $i$ ,  $I_\zeta$  is the household's income, and  $\bar{q}_0$  is its initial endowment of the numeraire; to ensure positive consumption of the numeraire, we assume income to be sufficiently large, with:  $I_\zeta > \int_{i \in \tilde{\Omega}} p(i) q^\zeta(i) di$ .

We shall further assume that each household supplies one unit of labour inelastically that can be hired by both a firm in the monopolistic sector and by producers in the competitive sector.<sup>7</sup> Denoting, with  $w$  and  $w_0$  the wage rate in the monopolistic sector and in the competitive sector respectively, the expected income of household  $\zeta$  employed by firm  $i$  will then be given by:

$$I^\zeta = w(i) l^\zeta(i) + w_0 l_0^\zeta,$$

where  $l^\zeta(i)$  and  $l_0^\zeta = 1 - l^\zeta(i)$  are the amount of work performed by the household in the monopolistic sector and in the competitive sector, respectively.<sup>8</sup> It is obvious that when  $w(i) > w_0$  a worker strictly prefers to work for a firm in the monopolistic sector, and the condition to have at least some employment in this sector requires that  $w(i) \geq w_0$ .

Maximisation of (1) subject to (2) yields the inverse individual demand for each variety produced by the monopolistic sector:

$$p(i) = \alpha - \delta q^\zeta(i) - \eta Q^\zeta, \quad (3)$$

where  $Q^\zeta = \int_{i \in \tilde{\Omega}} q^\zeta(i) di$  is total individual consumption of the differentiated good. Inverting (3) and aggregating over consumers yields the demand function facing each firm  $i$ :

$$q(i) = L \left[ \frac{\alpha}{(\delta + \eta N)} - \frac{1}{\delta} p(i) + \frac{\eta}{\delta(\delta + \eta N)} N \bar{p} \right] \quad (4)$$

<sup>7</sup>It is of course possible to envisage different employment configurations (e.g. with employment in only one of the sectors, or in more than one monopolistic firm). For simplicity, we rule out these cases by assumption as they would not substantially alter the qualitative nature of the results.

<sup>8</sup>As we shall see, no aggregate profits persist in equilibrium. Hence, income only depends on labour income.



where  $q(i) = Lq^\zeta(i)$ , and  $N$  is the measure of consumed varieties in  $\tilde{\Omega}$  with average price  $\bar{p} = \frac{1}{N} \int_{i \in \tilde{\Omega}} p(i) di$ . The price threshold for the demand for a variety to be positive is:

$$p_{\max} \equiv \frac{(\alpha\delta + \eta N \bar{p})}{\delta + \eta N}. \quad (5)$$

Thus,  $p_{\max}$  can be interpreted as an inverse measure of the toughness of competition in the industry. As is clear from (5),  $p_{\max}$  is positively related to  $\bar{p}$  and (given that, from (3),  $p(i) < \alpha$ ) it is negatively related to  $N$ : i.e. the lower their average price and the larger the number of varieties, the more competitive is the industry and the lower is the price a variety needs to have for its demand to be positive.

As is evident from (4), demand is independent of income; this is a key drawback of the quasi-linear utility function since it rules out general equilibrium income effects. However, in contrast to the Dixit-Stiglitz constant elasticity of substitution framework more commonly used in this literature, the price elasticity of demand here is not constant and does not solely depend on the degree of product differentiation. From (4) and (5), for a given price  $p(i)$ , the price elasticity of demand of firm  $i$  is given by:  $\epsilon_q(i) = \left| \frac{\partial q(i)}{\partial p(i)} \frac{p(i)}{q(i)} \right| = [(p_{\max}/p(i)) - 1]^{-1}$  which falls in  $p_{\max}$  (i.e. it increases in the number of varieties  $N$  and falls in the average price  $\bar{p}$ ). Thus, the tougher is competition in the industry the higher will be the price elasticity of demand for a given variety. Clearly, for a given  $p_{\max}$ , the price elasticity of demand for a variety will be higher the higher is its price  $p(i)$ .

## 2.2 Production

Both sectors use labour as the only factor of production. In the competitive sector, one unit of the homogeneous good is produced with one unit of labour.

Prior to entry into the monopolistic sector, ex-ante identical firms need to incur a fixed cost  $f_E$  related to the set up of plants and production lines and to the research and development (R&D) activity required for the introduction of a new variety of the good. This cost, which is identical for all entrants, is in terms of the homogeneous good and is sunk after entry. Subsequent production occurs according to a constant returns to scale technology:

$$q(c) = \frac{l(c)}{c}. \quad (6)$$

where  $l$  is the firm's labour demand and  $c$  is its unit labour requirement. Given the uncertainty characterising the outcome of R&D efforts, it is only after making the irreversible investment  $f_E$  that a firm will learn how productive its technology is; we assume that  $c$  is drawn from some cumulative distribution,  $G(c)$ . Hence, there will emerge a distribution of entrants across marginal costs – with firms exhibiting, after entry, heterogeneous productivities. Since firms

with the same cost parameter  $c$  are symmetric, henceforth we shall index firms by  $c$  alone. Thus, a typical firm will have marginal production cost  $w(c)c$ , where  $w(c)$  is the wage paid to its workers, and operating profits:

$$\pi(c) = [p(c) - w(c)c] q(c). \quad (7)$$

Due to the assumption of a continuum of firms in the industry, a firm takes the number of competitors and the industry average price as given. Hence, the price and the quantity which solve the firm's maximisation problem must satisfy the following relationship:

$$q(c) = \frac{L}{\delta} [p(c) - w(c)c]. \quad (8)$$

Given the demand equation in (4), (8) then yields the optimal price set by the firm:

$$p(c) = \frac{w(c)c}{2} + \frac{\alpha\delta + \eta N\bar{p}}{2(\delta + \eta N)}. \quad (9)$$

Substituting (8) into (7), we obtain maximized operating profits:

$$\pi(c) = \frac{L}{\delta} [p(c) - w(c)c]^2. \quad (10)$$

It will prove useful, by substituting equation (8) into equation (6), to derive the quantity of labour demanded by a firm with cost parameter  $c$ :

$$l(c) = \frac{Lc}{\delta} [p(c) - w(c)c], \quad (11)$$

which can then be used to rewrite the maximised profits in (10) in terms of labour demand:

$$\pi(c) = \frac{\delta}{Lc^2} l^2(c). \quad (12)$$

Given that the entry cost is sunk, only firms capable of covering their marginal cost – i.e. with  $p(c) \geq w(c)c$  – will be able to survive in the market. Clearly, for active firms, it must be the case that  $p(c) \leq p_{\max}$  which, given (9), requires that  $w(c)c \leq p_{\max}$ . Thus, the lower is  $p_{\max}$  (and the tougher is competition in the industry), the lower will be the marginal cost that allows firms to break-even.

### 2.3 Unions

In the numeraire homogenous good sector, the labour market is perfectly competitive and all employers pay the same wage  $w_0$ . Since the price of the good and the value of the marginal product of labour in this sector are both fixed at unity,  $w_0$  is also equal to 1. Labour in the monopolistic sector is unionized. We adopt the right-to-manage model in which employment is determined unilaterally by the firm and the wage is determined via a bargaining process between firms and firm-specific unions.

The Nash bargaining solution to the firm specific right-to-manage model is obtained by:

$$\max_{w(c)} \Pi = v \log [V(w(c), l(c))] + (1 - v) \log [\pi(w(c), l(c)) - \pi_0(c)], \quad (13)$$

where  $0 < v \leq 1$  represents the bargaining power of the union,  $\pi_0(c)$  is the firm's reservation profit and  $V$  is the union's total labour rent. The case in which  $v = 1$  corresponds to the monopoly union model; instead, when  $v = 0$ , the model collapses into the no-union case considered in Melitz and Ottaviano [27]. Without loss of generality, we shall set  $\pi_0(c)$  at zero.<sup>9</sup> Union  $i$ 's total labour rent above the competitive wage paid to non-unionized workers is given by:

$$V(w(c), l(c)) = l(c)[w(c) - 1]. \quad (14)$$

Given (12) and (14), maximization of the Nash bargaining product in (13) subject to the labour demand equation in (11) and the equilibrium price in (9) yields the following wage equation:

$$w(c) = 1 + \frac{2v}{(v+2)c} [p(c) - c]. \quad (15)$$

Note that, for expressions (8) and (10) to be positive, it must be the case that  $p(c) \geq w(c)c$ . Given (15), this condition holds if and only if:

$$p(c) \geq c. \quad (16)$$

Condition (16), in turn, implies that  $w(c) \geq w_0 = 1$ . As is clear from (15), bargaining at the level of the firm then results in a distribution of firm specific wages, above the reservation wage, that depend on the cost parameter of firms.

The level of employment in the monopolistic sector is determined by demand; the remaining labour supply is absorbed by the competitive sector which will clear the labour market.<sup>10</sup>

## 2.4 The long-run autarkic equilibrium

Prior to entry into the industry, a firm's expected profit is  $\int_0^{c_D} \pi(c) dG(c) - f_E$  which needs to be non-negative for entry to occur. In the absence of entry restrictions, firms will continue to enter the industry until expected profits are driven to zero. Thus, the free-entry 'zero-profit' equilibrium requires:

$$\int_0^{c_D} \pi(c) dG(c) = f_E.$$

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<sup>9</sup>This is equivalent to assuming that a firm would have to stop production in case of a break-down of negotiations.

<sup>10</sup>Unionisation could be introduced in the homogenous sector as well. However, this sector serves as an 'anchor' in the model and fixes the reservation wage to the level that clears the labour market. Introducing unions in this sector would result in aggregate unemployment and require another mechanism to fix the reservation wage – the most plausible one being an unemployment benefit which, in turn, would require taxation and a government budget constraint. Although interesting, this case goes beyond the aims of this paper.

After having paid the fixed cost  $f_E$ , a firm will stay in the market and start producing only if it draws a sufficiently low unit labour requirement parameter  $c$  or will exit immediately otherwise. The entry condition above identifies a threshold, or cut-off, level of unit labour requirement  $c_D$  at which a firm will just break-even and which is defined by the following equivalent zero-profit condition:

$$c_D \equiv \sup \{c : \pi(c_D) = 0\}. \quad (17)$$

Substituting (15) into (10), and the resulting expression into (17) yields:

$$\pi(c_D) = 0 \iff p(c_D) = c_D w(c_D), \quad (18)$$

where  $p(c_D)$  and  $w(c_D)$  are the price and wage of marginal firms with unit labour requirement  $c_D$ . Thus,  $c_D$  denotes the upper limit of the range of  $c$  of firms actually producing in the industry. Entrants whose draw is such that  $c \leq c_D$  will remain in the market and start producing: of these, the non-marginal firms (i.e. those with  $c < c_D$ ) will earn gross (of the entry cost) positive profits. Entrants with a value of  $c > c_D$  will exit the market and forego the entry cost.

Substituting the price from equation (18) into the wage equation in (15) yields:

$$w(c_D) = 1. \quad (19)$$

i.e. the wage paid by the marginal firms equals the competitive wage. Noting that operating profits for the marginal firms are equal to zero, which implies  $p(c_D) = c_D$ , and substituting the wages in (15) and (19) into (9) and (8), the optimal prices and output levels of a typical firm can now be written as functions of  $c_D$ :

$$p(c) = \frac{(v+2)c_D + (2-v)c}{4} \quad \text{and} \quad q(c) = \frac{(2-v)L}{4\delta} (c_D - c). \quad (20)$$

Similarly, maximized profit levels can be written as:

$$\pi(c) = \frac{L(2-v)^2}{16\delta} (c_D - c)^2. \quad (21)$$

Thus, for a given  $v$ , firms with lower unit labour requirements will set lower prices, sell larger quantities, and have larger profits than less productive firms. These firms will also charge higher absolute markups<sup>11</sup> – defined as  $\mu(c) = p(c) - w(c)c$  and expressed in terms of  $c_D$  as:

$$\mu(c) = \frac{1}{4} (2-v) (c_D - c), \quad (22)$$

despite the fact that they will also pay higher wages, as seen by substituting  $p(c)$  from (20) into (15):

$$w(c) = 1 + \frac{v}{2} \left( \frac{c_D}{c} - 1 \right). \quad (23)$$

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<sup>11</sup>For  $v = 0$ , these results correspond to those in Melitz and Ottaviano [27].

The intuition for the negative relationship between the optimal negotiated wage and the cost parameter  $c$  is that a more productive firm offers its union a higher potential to capture some of the rents it earns in the product market. The primary source of these rents, in turn, is the firm's monopoly position in the industry. As shown, in this model, the price elasticity of demand is firm specific: for a given toughness of the competitive environment characterising the industry, it increases in the price of the firm and, given (20), in its cost parameter  $c$  (i.e.:  $\frac{\partial \epsilon_q(c)}{\partial c} > 0$ ). Thus, firms with higher costs, and facing a higher price elasticity of demand, offer their unions a lower rent extraction opportunity. Furthermore, a higher cost firm presents its union with a higher wage elasticity of labour demand – i.e.  $\frac{\partial \epsilon_w(c)}{\partial c} > 0$ , where  $\epsilon_w(c) = \left| \frac{\partial l(c)}{\partial w(c)} \frac{w(c)}{l(c)} \right|$ : given the trade-off between wage and employment, this implies that the incentive for unions to bid for higher wages falls as the cost parameter of the firm increases. Thus, the lower is the productivity of a firm, the lower will be its degree of monopoly power in the product market and the higher will be the wage elasticity of labour demand facing its union; as a result, the lower will be the rent that a union will extract from the firm and the extent to which the negotiated wage will depart from the competitive wage.<sup>12</sup> Hence, unionisation weakens the relative cost advantage of high productivity firms, and we can state that:

**Proposition 1** *Unionisation mitigates the effects of inter-firm heterogeneity in productivity on the cost distribution of firms.*

This result and the dependence of the wage on the productivity of the firm – which will in turn affect all other endogenous variables in the model – represents a first important departure from the Melitz and Ottaviano [27] model in which the marginal cost of the firm was ultimately solely dependent on its productivity parameter.

As is now common in the literature, we adopt a Pareto distribution as the specific parameterization of  $G(c)$ .<sup>13</sup> This distribution has a higher unit labour requirement bound  $c_M$  and shape parameter  $\kappa \geq 1$ :

$$G(c) = \left( \frac{c}{c_M} \right)^\kappa, \quad c \in [0, c_M]. \quad (24)$$

This parameterization implies that high productivity firms are less frequent than low productivity ones, with the shape parameter  $\kappa$  indexing the dispersion of the unit labour requirement draws. When  $\kappa = 1$ , the unit labour requirement distribution is uniform on  $[0, c_M]$ . As  $\kappa$  increases, the distribution is more concentrated at higher values of  $c$ . As  $\kappa$  goes to infinity, the distribution becomes

<sup>12</sup>Essentially, the negative effect of an increase in wage on a firm's unit labour costs and thus on employment is higher in a high cost firm. Even accounting for the fact that the level of employment per unit of output is higher the lower the productivity of the firm, this translates into a higher wage elasticity of labour demand in high cost firms – and hence in a higher incentive for unions to contain wage demands.

<sup>13</sup>Del Gatto *et al* [10] show that the Pareto distribution offers a good approximation of the productivity distribution of firms in 11 European Countries.

degenerate at  $c_M$ . Given (24), the average unit labour requirement of entrants is given by  $\bar{c} = c_M \kappa / (\kappa + 1)$ , with variance equal to  $\bar{c} / [\kappa(\kappa + 2)]$ . Thus, the higher is  $c_M$ , the higher will be the mean and the variance of the unit labour requirement draws.

Making use of this parameterisation, we can now determine the market structure of the industry. Substituting (24) into (21) and imposing the zero-profit free-entry condition yields the following closed form solution for the cut-off level of  $c$ :<sup>14</sup>

$$c_D = \left[ \frac{8\delta(\kappa + 1)(\kappa + 2)f_E c_M^\kappa}{L(2 - v)^2} \right]^{1/(\kappa + 2)}. \quad (25)$$

Substituting (25) into equations (20)-(24) we can obtain the average levels of the unit labour requirements, prices, mark-ups, outputs, profits, and wages, respectively given as:

$$\begin{aligned} \bar{c} &= \frac{\kappa}{\kappa + 1} c_D, \quad \bar{p} = \frac{(4\kappa + v + 2)}{4(\kappa + 1)} c_D, \quad \bar{\mu} = \frac{1}{4} (2 - v) \frac{c_D}{(\kappa + 1)} \\ \bar{q} &= \frac{(2 - v)L}{4\delta(\kappa + 1)} c_D, \quad \bar{\pi} = \frac{L(v - 2)^2 c_D^2}{8\delta(\kappa + 1)(\kappa + 2)}, \quad \bar{w} = 1 + \frac{v}{2(\kappa - 1)}. \end{aligned} \quad (26)$$

Noting that for the marginal firms it must be the case that  $p_D = p_{\max} = c_D$ , substitution of  $\bar{p}$  from (26) into (5) allows to determine the number of firms selling in the economy as:

$$N = \frac{4(\kappa + 1)\delta\alpha - c_D}{\eta(2 - v)c_D}. \quad (27)$$

Given (27), the number of entrants can then be obtained from:

$$N_E = N/G(c_D). \quad (28)$$

The following proposition summarises the effects of union power on the long-run equilibrium of the model.

**Proposition 2** *An increase in the bargaining power of unions  $v$  will have: (i) a selection-softening effect, reducing the toughness of competition in the industry via an increase in the value of  $c_D$ ; (ii) a counter-competitive effect, by increasing average prices, and reducing average markups and profits; (iii) a wage inequality effect by increasing wage dispersion; and (iv) a pro-variety effect, by increasing the mass of firms selling in the economy when the preference for the differentiated good is sufficiently strong.*

Inspection of (25) shows that  $\frac{\partial c_D}{\partial v} > 0$ , i.e. a higher bargaining power of unions reduces the minimum level of productivity required to survive in equilibrium. This essentially amounts to a reduction in the toughness of competition

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<sup>14</sup> A sufficient condition for  $c_D < c_M$  to hold is that  $\sqrt{[8\delta(\kappa + 1)(\kappa + 2)f_E]/[L(2 - v)^2]} < c_M$ , which we impose.

and a softening of the competitive selection process within the industry – thus leading to more entry of relatively less efficient firms. Underpinning this result is the effect that the bargaining power of unions has on firm-specific wages. As discussed, for a given  $v$ , a union will be able to negotiate a higher wage the higher is the productivity of its firm. In addition, however, the responsiveness of wages to changes in union power is also higher in relatively more productive firms: from equation (23), it can be verified that the elasticity of the wage with respect to changes in  $v$  falls in  $c$  (i.e.  $\frac{\partial \epsilon_{w,v}(c)}{\partial c} < 0$ , where:  $\epsilon_{w,v}(c) = \frac{\partial w(c)}{\partial v} \frac{v}{w(c)}$ ). Thus, *for a given cut-off*, an increase in  $v$  will translate in relatively higher wage demand increases in relatively more productive firms – i.e. it will hurt (via a higher wage) more efficient firms relatively more than less efficient ones – and thus result in a redistribution of market shares towards less efficient producers. Inspection of (26) reveals that this change in the efficiency composition of the industry, in turn, is accompanied by a counter-competitive effect reflected in a lower average level of productivity (i.e. a higher  $\bar{c}$ ), higher average prices ( $\bar{p}$ ), lower average quantities ( $\bar{q}$ ), and a reduction in both the average markup ( $\bar{\mu}$ ) and profit ( $\bar{\pi}$ ). The increase in the cut-off resulting from an increase in  $v$  will also lead to an increase in the dispersion of wages, as can be seen using the average wage  $\bar{w}$  in (26) to obtain the variance of wages:  $\sigma_w^2 = \frac{v^2 \kappa}{4(\kappa-1)^2(\kappa-2)}$ , which increases in  $v$ . Despite these effects, however, an increase in the bargaining power of unions may result in a larger mass of firms producing in the industry if the preference for the differentiated good (as reflected by  $\alpha$ ) is sufficiently strong: as is clear from equation (27),  $\frac{\partial N}{\partial v} > 0$  if  $\alpha > (\kappa + 2) c_D / \kappa$ .<sup>15</sup>

Finally, note that – as can be seen from (25) and (23) – an increase in the size of the economy reduces the cut-off level  $c_D$  and, consequently, the wage set by each firm.

## 2.5 Welfare

Before extending the model to an open economy setting, it is interesting to examine the effects of unionisation on the level of welfare.

Since free entry implies that aggregate profits vanish in equilibrium, we measure welfare by consumers' indirect utility. The indirect utility function of a typical consumer  $\zeta$  is given by:

$$W_\zeta \equiv I_\zeta + \bar{q}_0 + B. \quad (29)$$

The term  $B$  in (29) is common to all consumers and is defined as:

$$B \equiv \frac{1}{2} \left( \eta + \frac{\delta}{N} \right)^{-1} (\alpha - \bar{p})^2 + \frac{1}{2} \frac{N}{\delta} \sigma_p^2, \quad (30)$$

where  $\sigma_p^2$  is the variance of prices, given by:

$$\sigma_p^2 = \frac{(2-v)^2}{16} \frac{\kappa}{(\kappa+2)(\kappa+1)^2} (c_D)^2. \quad (31)$$

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<sup>15</sup>For  $N$  to be positive,  $\alpha$  needs to be greater than  $c_D$ .

Given (30), comparative statics on (29) reveals that welfare decreases in  $\bar{p}$  and increases in both  $N$  and  $\sigma_p^2$ . The increase in welfare resulting from a higher  $N$  reflects the standard love of variety effect. For a given  $\bar{p}$ , increases in  $\sigma_p^2$  have a positive effect on welfare (as in Melitz and Ottaviano [27]) since they induce consumers to re-optimize and reallocate expenditure towards both cheaper varieties and the numeraire good. For a given value of the cut-off  $c_D$ ,  $\bar{p}$  is increasing in  $v$ , and  $\sigma_p^2$  is decreasing in  $v$ . Substituting  $\bar{p}$  from (26) and  $\sigma_p^2$  from (31) in (30),  $B$  can be rewritten as:

$$B = \frac{1}{4\eta} (\alpha - c_D) \left[ 2\alpha - \frac{c_D (2\kappa + v + 2)}{(\kappa + 2)} \right], \quad (32)$$

where the condition that  $\alpha > c_D$  implies that  $B > 0$ .

The average indirect utility in the economy is given by:

$$\bar{W} \equiv \frac{\sum W_\zeta}{L} = \bar{I} + \bar{q}_0 + B,$$

where the average household's income,  $\bar{I}$ , is:

$$\bar{I} \equiv \frac{\overline{VC} N + w_c(L - \bar{l}N)}{L} = \frac{(\overline{VC} - \bar{l})N}{L} + 1.$$

In the above,  $\overline{VC}$  is the average variable cost of production sustained by a firm (i.e. the *average labour income* generated by a firm) and  $\bar{l}$  is the average labour demand of firms in the monopolistic sector. These are respectively given by:

$$\overline{VC} = \frac{L(2-v)(\kappa+v)}{4\delta(\kappa+1)(\kappa+2)} (c_D)^2,$$

and

$$\bar{l} = \frac{L(2-v)\kappa}{4\delta(\kappa+1)(\kappa+2)} (c_D)^2.$$

It then follows that  $\frac{\partial \bar{I}}{\partial v} \gtrless 0$  if, and only if,  $\alpha \gtrless c_D [2v + 4 + \kappa(2-v)] / [\kappa(2-v) + 4]$ , i.e. the average household's income increases in  $v$  only if the preference for the differentiated good is sufficiently strong. As discussed earlier, when  $\alpha$  is sufficiently large, the mass of firms in the industry increases in  $v$ . In this instance, total employment in the monopolistic sector can also be shown to increase in  $v$  – and so will the proportion of workers in the economy that perceive the higher monopolistic wage.<sup>16</sup> Also, from (32) we obtain:

$$\frac{\partial B}{\partial v} = -\frac{1}{4\eta} \frac{\partial c_D}{\partial v} \left[ 2\alpha - \frac{c_D(2\kappa+v+2)}{(\kappa+2)} + \frac{(\alpha-c_D)(2\kappa+v+2)}{(\kappa+2)} \right] - \frac{1}{4\eta} \frac{(\alpha-c_D)c_D}{\kappa+2} < 0 \quad (33)$$

Note that, as can be easily verified from (26) and (31),  $\frac{\partial \bar{p}}{\partial v} > 0$  and  $\frac{\partial \sigma_p^2}{\partial v} < 0$ . Thus, the negative effects of  $v$  on  $B$  via a higher average price and a lower variance of prices more than offset its positive effect via an increase in the mass of varieties  $N$ . Thus:

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<sup>16</sup>The condition for  $\frac{\partial N \bar{I}}{\partial v} > 0$  to hold is  $\alpha > 2c_D$ .



**Proposition 3** *An increase in the bargaining power of unions increases welfare if the preference for the differentiated good is sufficiently strong.*

When preferences for the differentiated good are sufficiently weak (i.e. for small values of  $\alpha$ ), an increase in the bargaining power of unions will unambiguously lower welfare, since it reduces both  $B$  and  $\bar{I}$ . As discussed, a rise in  $v$  has a selection-softening and a counter-competitive effect that result in lower average productivity in the industry – and hence in higher average prices as well as in a lower variance of prices. If consumers’ love of variety is sufficiently low, an increase in union power will also have a counter-variety effect that reduces the mass of varieties produced in the industry. In this instance, stronger unions will unambiguously lower welfare. However, when preferences for the differentiated good are sufficiently strong, this result can be reversed, as the pro-variety effect of an increase in  $v$  more than offsets the adverse counter-competitive effects on the average price and on the variance of prices. Thus, when the value placed by consumers on product differentiation is high, more powerful unions will increase welfare, despite the worsening of the average productivity of firms, by reducing the toughness of competition in the industry and allowing for a larger mass of firms to survive in equilibrium – an effect that will also result in higher average household incomes.<sup>17</sup>

Unionisation, therefore, influences the operation of the standard forces (such as number of firms and prices) that affect welfare in this type of models. Ultimately, via its effects on firm selection, union power does not have unambiguously negative effects on welfare – as implied by the standard ‘distortionary’ view of unionisation.

### 3 Two-Country World

In this section we extend the analysis to consider two-countries, home and foreign, and examine how international differences in union bargaining power affect inter-market linkages and relative performance. We use an asterisk to refer to foreign variables and the subscripts  $D$  and  $X$  to denote variables associated with domestic and export sales, respectively. Whenever appropriate and for ease of exposition, the model will be discussed in terms of the home country’s variables only.

The two economies, endowed respectively with a mass of households  $L$  and  $L^*$ , are assumed to be symmetric both in consumer preferences and in the production technologies of the two sectors. We shall, however, allow for asymmetries to exist in population size, trade barriers and bargaining power of unions. The homogeneous good is assumed to be freely traded. Thus, continuing to use this good as the numeraire implies that the wage in this sector is equal to one in both countries. In the monopolistically competitive sector, markets are segmented; we shall further assume that trade occurs at a cost – with firms in

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<sup>17</sup>The fact that welfare in this model depends on both market size and mass of producers is a key difference with the results obtained by Egger and Kreickemeier [14].

the home (foreign) country incurring a per-unit trade cost  $\tau > 1$  ( $\tau^* > 1$ ) when selling their output to consumers located abroad. Therefore, a unit of the good produced in the home country with cost  $w(c)c$  will be delivered to consumers abroad at a cost  $\tau w(c)c$ .

In each country, firms entering the monopolistic sector draw their unit labour requirement coefficients  $c$  simultaneously from an identical Pareto distribution  $G(c)$  after having paid the fixed entry cost  $f_E$ . A firm will then decide whether to produce or not, or whether to export or not, depending on the profits it expects to earn at home and abroad, conditional on the productivity distribution of the entrants that will eventually decide to produce.

Due to market segmentation, the toughness of competition in firms' domestic and export markets is different – i.e. the price threshold for positive demand is market-specific, with:

$$p_{\max} \equiv \frac{(\alpha\delta + \eta N\bar{p})}{\delta + \eta N} \quad \text{and} \quad p_{\max}^* \equiv \frac{(\alpha\delta + \eta N^*\bar{p}^*)}{\delta + \eta N^*}. \quad (34)$$

Given that production occurs according to a constant returns to scale technology, a firm deciding to export will have two separate *profit centres* – one linked to production for the domestic market and one linked to its export activity – and will maximise the profits it earns from domestic and export sales, given respectively by  $\pi_D(c)$  and  $\pi_X(c)$ , independently. The resulting prices and markups are profit-centre (or market) specific and so are the price elasticities of demand facing the firm. Following the same procedure as in the closed economy, the firm's labour demands to produce for the domestic market,  $l_D(c)$ , and that to produce for the export market,  $l_X(c)$ , can then be found to be:

$$l_D(c) = \frac{Lc}{\delta} [p_D(c) - w(c)c] \quad \text{and} \quad l_X(c) = \frac{\tau L^*c}{\delta} [p_X(c) - \tau w(c)c]. \quad (35)$$

which can be used to write the maximized profits as:

$$\pi_D(c) = \frac{\delta [l_D(c)]^2}{Lc^2} \quad \text{and} \quad \pi_X(c) = \frac{\delta [l_X(c)]^2}{\tau L^*c^2}. \quad (36)$$

Thus, firms with cost parameter  $c$  produce for the domestic market if, and only if,  $\pi_D(c) \geq 0$ , and export to the foreign market if, and only if,  $\pi_X(c) \geq 0$ .

### 3.1 Unions

In the monopolistic sector workers are unionised. As noted, due to market segmentation, exporting firms in this sector face different competitive pressures – and hence face different elasticities of demand and enjoy different monopoly positions – in their domestic and export markets. Thus, not only will the rent extraction ability of unions vary between firms but also between the different activities (or profit centres) of a firm.

In recent years, the need to recognize not only firm-specific but also plant (or profit-centre) specific conditions within the same firm has motivated the

drive across the OECD (even in countries traditionally characterised by high levels of collective bargaining coverage) towards a reduction in the degree of centralisation of wage bargaining, down from the industry level to the level of the firm and, further, to the level of individual plants within a firm – resulting in a firm signing a number of different contracts with unions (Kamakura, [22]). Above-average numbers of agreements per firm are to be found in the chemical, electricity, energy, metalworking, telecommunications and electronics industries – with their number typically increasing in the size of the establishment; for example, in the chemical industry in Finland 90% of firms have on average 13 contracts per establishment (Kamakura, [22]). Local bargaining is particularly dominant in the export sector, as the perceived need to attune pay settlements to the competitive position of the different activities of the firm is higher (Jackson, [20]). Essentially, firm and plant level agreements are seen as a means to ensure that wage settlements (or other negotiated issues) reflect variations in productivity and profitability across both firms and profit-centres within individual firms.<sup>18</sup>

Against this background, it is therefore relevant to envisage two scenarios: (i) a *profit-centre* level bargaining, in which each firm-union pair undertakes two separate bargaining processes: one to determine the wage paid to workers employed to produce for the domestic market and the other to set the wage for the workers employed to produce for exports; and (ii) a *firm level bargaining*, in which the firm and the union negotiate a unique wage for all the labour employed by the firm.

The Nash bargaining problem for firms producing only for the domestic market is given by (13) which is solved subject to the profit  $\pi_D(c)$  in (36) and the union's total labour rent in (14) to yield:

$$w_D(c) = 1 + \frac{2v}{(v+2)c} [p_D(c) - c], \quad (37)$$

that has the same functional form as the autarkic wage.

For exporting firms, the wage determination process will differ depending on whether they bargain with their union at the profit-centre or at the firm level. With a profit-centre level bargaining,  $w(c) = (w_D(c), w_X(c))$  where  $w_D(c)$  and  $w_X(c)$  are a typical firm-union pair's *domestic* and *export* wage, respectively.  $w_D(c)$  is determined by solving the same bargaining problem of a non-exporting firm and will be given by (37). The wage paid to the workers employed in producing for the export market will instead be set by solving:

$$\max_{w_X(c)} \Pi_X = v \log [l_X(c) (w_X(c) - 1)] + (1 - v) \log \left[ \frac{\delta [l_X(c)]^2}{\tau L^* c^2} \right],$$

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<sup>18</sup>In a study for the CBI, Brown [7] documents the increasing practice in the UK of decentralising internal bargaining at the sub-firm level. Leopold and Jackson [23] discusses the case of the British company Coats Viyella PLC which opted out of national industry negotiations in 1989 and decentralised bargaining to 16 '*profit centres*' – that could cover multiple or individual plants, but also be limited to specific production lines within individual plants – defined on the basis of the customer base and market pressures facing the different activities.

subject to the labour demand in (35), to obtain:

$$w_X(c) = 1 + 2 \frac{v}{(v+2)c} \left( \frac{p_X(c)}{\tau} - c \right). \quad (38)$$

Following the same reasoning as for the closed economy, it is easy to verify that  $p_X(c) \geq \tau c$ ; (38) then implies that  $w_X(c) \geq 1$ .

In the firm-level bargaining regime, an exporting firm with cost parameter  $c$  will negotiate a unique wage  $w_U(c)$  with its union covering both its domestic and export profit-centres. In this instance,  $w(c) = w_U(c)$  which is obtained by solving:

$$\begin{aligned} \max_{w_U(c)} \Pi_U &= v \log [(l_D(c) + l_X(c)) (w_U(c) - 1)] + \\ &\quad (1 - v) \log [\pi_D(w_U(c), l(c)) + \pi_X(w_U(c), l_X(c))], \end{aligned}$$

subject to the labour demands and profits given in (35) and (36), to yield the first-order condition:

$$\frac{\partial \Pi_U}{\partial w_U(c)} = -\frac{vc^2 (L + L^* \tau^2)}{2\delta (l_D(c) + l_X(c))} + \frac{v}{(w(c) - 1)} - \frac{(1 - v) (l_D(c) + \tau l_X(c))}{\frac{\delta}{c^2} \left( \frac{1}{L} l_D(c)^2 + \frac{1}{\tau L^*} l_X(c)^2 \right)} = 0 \quad (39)$$

which is highly non-linear and does not allow to obtain an analytical solution for the wage in the general case of  $0 < v < 1$ . For  $v = 1$ , i.e. for the limiting case of monopoly unions, (39) can be solved to obtain:

$$w_U(c) = \frac{1}{3} + \frac{2}{3c} \frac{L p_D(c) + \tau L^* p_X(c)}{L + L^* \tau^2}. \quad (40)$$

For given productivity cut-offs, this optimal wage rule can be written as a convex combination of the two wages obtained via the profit-centre level wage bargaining:

$$w_U(c) = \Phi w_D(c) + (1 - \Phi) w_X(c) \quad (41)$$

where  $\Phi = \frac{L}{L + L^* \tau^2}$  can be obtained by substituting the expressions for  $w_U(c)$ ,  $w_D(c)$ , and  $w_X(c)$  into (41).  $\Phi$  gives a measure of the trade-cost-adjusted relative size of the domestic market: the larger is the relative size of the domestic economy and/or the higher is the accessibility of the foreign market (i.e. the larger is  $L$  and the smaller is  $\tau$ ), the closer will be the unique wage to the domestic wage set under profit-centre level bargaining. Figure 1 plots  $w_U$  together with  $w_D$  and  $w_X$  numerically for the general case of  $0 < v < 1$  and shows the unique firm-level wage to lie between the two profit-centre specific wages; specifically, we find that:  $w_X(c) < w_U(c) < w_D(c)$ .

Insert Figure1 about here

In the interest of conciseness and analytical tractability, and given our aim to examine the effects of variations in the bargaining power of unions in and between countries, in the remainder of the paper the primary focus of our analysis

will be on the profit-centre level bargaining regime. The equilibrium wages and productivity cut-offs for the firm-level bargaining case with monopoly unions are derived in the Appendix and we shall compare results between the two bargaining regimes whenever relevant.

### 3.2 The long-run two-country equilibrium

As in autarky, free entry and exit into the industry implies that expected profits are driven to zero in equilibrium. The possibility of exporting, however, will result in the emergence of two cut-offs for  $c$  that define, respectively, the upper limit of the range of  $c$  over which firms produce only for the local market, and the upper limit of the range of  $c$  over which firms export. Denoting these two cut-off points as  $c_D$  and  $c_X$  respectively, for a given number of entrants,  $N_E$ , a mass  $N_D = G(c_D)N_E$  of firms will sell only in the domestic market and a mass  $N_X = G(c_X)N_E$  of firms will export. Given that firms would be forced to leave if their profits were negative, the cut-off levels for firms that sell in the domestic market only and for firms that export are defined respectively by:

$$\begin{aligned} c_D &\equiv \sup \{c : \pi_D(c_D) = 0\}, \\ c_X &\equiv \sup \{c : \pi_X(c_X) = 0\}, \end{aligned}$$

which describe the (zero-profit) indifference conditions of marginal firms and imply that firms that are just able to cover their marginal costs for domestic and export sales are, respectively, characterized by:

$$\begin{aligned} \pi_D(c_D) &= 0 \iff p_D(c_D) = w_D(c_D)c_D, \\ \pi_X(c_X) &= 0 \iff p_X(c_X) = \tau w_X(c_X)c_X, \end{aligned} \tag{42}$$

where  $p_D(c_D)$  and  $w_D(c_D)$  are the price and the wage of the domestic market firms with  $c = c_D$ , and  $p_X(c_X)$  and  $w_X(c_X)$  are the export price and wage of exporting firms with  $c = c_X$ .<sup>19</sup> Substituting the relevant price from (42) into (37) and (38), yields:

$$w_D(c_D) = 1 \quad \text{and} \quad w_X(c_X) = 1, \tag{43}$$

i.e., the wage paid by both types of marginal firms equals the competitive wage.<sup>20</sup> It then follows that (42) can be rewritten as:

$$p_D(c_D) = c_D \quad \text{and} \quad p_X(c_X) = \tau c_X. \tag{44}$$

As we shall show,  $c_D > c_X$ ; then, from (42), three types of entrants can be identified: (i) low productivity firms, with  $c > c_D$ , that will not be able to produce – and hence will exit; (ii) firms with intermediate productivity levels, with  $c_X < c \leq c_D$ , that produce only for the local market; and (iii) high

<sup>19</sup>Note that (42) also holds for the case of firm level bargaining, in which  $w_D = w_X = w_U$ .

<sup>20</sup>For the case of  $v = 1$  and with symmetric countries, it can be verified from equation (66) in the Appendix that  $w_U(c_X) \geq w_U(c_D) = 1$ .

productivity firms, with  $c \leq c_X$ , that produce for both the domestic and the export market. Making use of (44) and the wages in (37) and (38), the optimal prices and output levels for domestic and export sales can be written as functions of the cut-offs:

$$\begin{aligned} p_D(c) &= \frac{(v+2)c_D + (2-v)c}{4}, & q_D(c) &= \frac{(2-v)L}{4\delta} (c_D - c), \\ p_X(c) &= \frac{\tau[(v+2)c_X + (2-v)c]}{4}, & q_X(c) &= \frac{\tau(2-v)L^*}{\delta 4} (c_X - c), \end{aligned} \quad (45)$$

with maximized profit levels respectively given by:

$$\begin{aligned} \pi_D(c) &= \frac{L(2-v)^2}{16\delta} (c_D - c)^2, \\ \pi_X(c) &= \frac{\tau^2 L^* (2-v)^2}{16\delta} (c_X - c)^2. \end{aligned} \quad (46)$$

Similarly, the absolute markups obtained from domestic and export sales by a firm with cost parameter  $c$  can be written as:

$$\mu_D(c) = \frac{1}{4} (2-v) (c_D - c) \quad \text{and} \quad \mu_X(c) = \frac{\tau}{4} (2-v) (c_X - c);$$

substituting prices from (45) into (37) and (38), the wage equations can be written as:

$$w_D(c) = 1 + \frac{v}{2} \left( \frac{c_D}{c} - 1 \right) \quad \text{and} \quad w_X(c) = 1 + \frac{v}{2} \left( \frac{c_X}{c} - 1 \right). \quad (47)$$

Thus, for given values of  $v$  and  $\tau$ , firms with lower unit labour requirements set lower prices, sell larger quantities, have higher profits and charge higher (absolute) markups than less efficient firms in both their domestic and export markets – despite the fact that they pay higher wages. As in the closed economy, firms with lower values of  $c$  enjoy a lower price elasticity of demand and a better monopoly position in their market (be it domestic or foreign). This gives their unions a higher potential for rent extraction and, due to a lower wage elasticity of labour demand, a higher incentive to set higher wages. As we show in the Appendix (for the monopoly union case), more productive firms would pay higher wages even under the firm-level bargaining regime (in which an exporting firm pays the same wage to all its workers).

### 3.2.1 The efficiency cut-offs and market structure

In a two-country setting, the two countries' efficiency cut-off points need to be determined jointly via the imposition of the zero expected profits free-entry and exit conditions. For the home country, this is:

$$\int_0^{c_D} \pi_D(c) dG(c) + \int_0^{c_X} \pi_X(c) dG(c) = f_E.$$

which, using the parametrization in (24) and the optimized profits in (46), can be rewritten as:

$$Lc_D^{\kappa+2} + \tau^2 L^* c_X^{(\kappa+2)} = \frac{8\delta c_M^\kappa (\kappa+1)(\kappa+2) f_E}{(2-v)^2}.$$

Note that, from (42) and (43), a relationship can be derived between the cut-off facing domestic producers in one country and that facing exporters from the other country, that is:

$$c_X^* = \frac{c_D}{\tau^*}, \quad (48)$$

which depends on the accessibility of the home country from the foreign country (determined by  $\tau^*$ ). Making use of this relationship in the zero expected profit conditions for both countries, we obtain the following system of equations:

$$\begin{cases} Lc_D^{(\kappa+2)} + \tau^{-\kappa} L^* c_D^{*(\kappa+2)} = \frac{8\delta c_M^\kappa (\kappa+1)(\kappa+2) f_E}{(2-v)^2} \\ L^* c_D^{*(\kappa+2)} + \tau^{*(-\kappa)} Lc_D^{(\kappa+2)} = \frac{8\delta c_M^\kappa (\kappa+1)(\kappa+2) f_E}{(2-v^*)^2} \end{cases},$$

which can be solved to derive  $c_D$  and  $c_D^*$ . Defining  $\rho \equiv \tau^{-\kappa} \in (0, 1)$ , which can be interpreted as the degree of ‘freeness’ of trade, we obtain:

$$\begin{aligned} c_D &= \left\{ \frac{8\delta c_M^\kappa (\kappa+1)(\kappa+2) f_E \left[ (2-v^*)^2 - (2-v)^2 \rho \right]}{L (2-v)^2 (2-v^*)^2 (1-\rho\rho^*)} \right\}^{\frac{1}{\kappa+2}}, \\ c_D^* &= \left\{ \frac{8\delta c_M^\kappa (\kappa+1)(\kappa+2) f_E \left[ (2-v)^2 - (2-v^*)^2 \rho^* \right]}{L^* (2-v)^2 (2-v^*)^2 (1-\rho\rho^*)} \right\}^{\frac{1}{\kappa+2}}, \end{aligned} \quad (49)$$

Making use of the relationship in (48) and the two countries’ domestic cut-offs in (49), it is then straightforward to obtain the two countries’ export cut-offs:

$$\begin{aligned} c_X &= \rho^{\frac{1}{\kappa}} \left\{ \frac{8\delta c_M^\kappa (\kappa+1)(\kappa+2) f_E \left[ (2-v)^2 - (2-v^*)^2 \rho^* \right]}{L^* (2-v)^2 (2-v^*)^2 (1-\rho\rho^*)} \right\}^{\frac{1}{\kappa+2}}, \\ c_X^* &= \rho^{*\frac{1}{\kappa}} \left\{ \frac{8\delta c_M^\kappa (\kappa+1)(\kappa+2) f_E \left[ (2-v^*)^2 - (2-v)^2 \rho \right]}{L (2-v)^2 (2-v^*)^2 (1-\rho\rho^*)} \right\}^{\frac{1}{\kappa+2}} \end{aligned} \quad (50)$$

From (49) and (50), the condition ensuring that both  $c_D$  and  $c_X^*$  are positive is:  $(2-v^*)^2 > (2-v)^2 \rho$ , whilst  $c_D^*$  and  $c_X$  are positive if  $(2-v)^2 > (2-v^*)^2 \rho^*$ .

Comparison of (49) and (25) shows that, as in Melitz and Ottaviano [27], when countries are symmetric, the domestic cut-off under trade is lower than that in autarky; by increasing product market competition, thus making it more difficult to survive in the domestic market and forcing less efficient firms to exit,

trade raises aggregate productivity. A better access to the foreign country (i.e. a larger  $\rho$ ) will, other things equal, reduce the domestic cut-off and increase the export cut-off, whilst an increase in the level of accessibility of the home country by foreign exporters, i.e. a higher  $\rho^*$ , will increase the domestic cut-off and reduce the export cut-off.<sup>21</sup> An increase in the domestic and foreign market size make it more difficult to survive in the domestic and export market respectively – i.e. a larger  $L$  and a larger  $L^*$  reduce  $c_D$  and  $c_X$ , respectively. The intuition for this is that, with quasi-linear preferences, in a larger market firms face a tougher competitive pressure and price on a more elastic segment of their demand curve, thus charging lower mark-ups. As a result, a larger destination market for their product (be it domestic or foreign) increases the minimum efficiency required for firms to break-even. These results are consistent with those obtained by Melitz and Ottaviano [27] – as can be seen by setting  $v = v^* = 0$  in (49) and (50)

As for the effect of the bargaining power of unions on the cut-offs, given the condition required to have a positive value of  $c_D$  and  $c_X$ , (49) and (50) yield:

$$\begin{aligned} \frac{\partial c_D}{\partial v} &> 0, & \frac{\partial c_X}{\partial v} &< 0 \\ \frac{\partial c_D}{\partial v^*} &< 0, & \frac{\partial c_X}{\partial v^*} &> 0 \end{aligned}$$

**Proposition 4** (1) *An increase in the bargaining power of domestic unions will have: (i) a selection-softening effect for domestic firms, by reducing the toughness of competition in the domestic market, and (ii) a selection-toughening effect for exporters, by increasing the toughness of competition in the foreign market.* (2) *An increase in the bargaining power of foreign unions will have: (i) a selection-toughening effect for domestic firms, by increasing the toughness of competition in the domestic market, and (ii) a selection-softening effect for exporters, by reducing the toughness of competition in the foreign market.*

As we saw, for a given  $v$ , unions paired with more efficient firms will be able to negotiate higher wages than those in firms with higher unit labour requirements. Moreover, as in autarky, an increase in union power will translate in relatively higher wage demand increases in relatively more efficient firms (since the elasticity of wages to changes in  $v$  falls in the cost parameter of the firm) – and hence will hurt exporters relatively more than domestic-only firms. As a result, an increase in  $v$  softens competition in the domestic market and reduces the minimum efficiency required to break even in that market (i.e.  $c_D$  increases). Due to the higher wages, the minimum efficiency required to be able to export, however, increases if unions become more powerful: i.e. a higher  $v$  reduces the export cut-off  $c_X$  – and hence increases the average efficiency of exporters. This analysis further implies that: (i) firms exporting to a country whose unions

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<sup>21</sup>As we show in the Appendix for the case of symmetric countries and monopoly unions, firm-level wage setting would also result in an export cut-off smaller than the domestic cut-off. The effects of trade liberalisation on the cut-off are also qualitatively the same as in the profit-centre level bargaining examined here, as shown in Figure A.1 in the Appendix.



have become more powerful will face a softer competition from domestic firms in that market; (ii) domestic firms in a market will face a tougher competition from exporters based in a country whose union power has increased.

To determine the total mass of firms selling in the (home) market, first note that  $p_D(c_D) = c_D = p_{\max}$ . Substituting  $c_D$  and  $c_X^*$  from (49) and (50) into the expression for  $p_D(c)$  (and its equivalent for  $p_X^*(c)$ ) from (45), and making use of (48), the average price of all the varieties (domestically produced and imported) sold in the country can then be found to be:

$$\bar{p} = \left[ \frac{N_D}{N_D + N_X^*} (4\kappa + v + 2) + \frac{N_X^*}{N_D + N_X^*} (4\kappa + v^* + 2) \right] \frac{c_D}{4(\kappa + 1)}. \quad (51)$$

Substituting the number of domestic producers,  $N_D = G(c_D)N_E = \left(\frac{c_D}{c_M}\right)^\kappa N_E$ , and the number of foreign producers exporting to the home market,  $N_X^* = G(c_X^*)N_E^* = \left(\frac{c_X^*}{c_M}\right)^\kappa N_E^*$ , into (51) and making use of (48), we can rewrite  $\bar{p}$  as follows:

$$\bar{p} = \frac{[N_E(4\kappa + v + 2) + \rho^* N_E^*(4\kappa + v^* + 2)] c_D}{4(\kappa + 1)(N_E + \rho^* N_E^*)}. \quad (52)$$

Combining (51), with the threshold price in (34) then yields the total number of firms selling in the country:

$$N = N_D + N_X^* = \left(\frac{c_D}{c_M}\right)^\kappa (N_E + \rho^* N_E^*). \quad (53)$$

Substituting (52) and (53) into  $c_D = \frac{1}{\eta N + \delta} (\delta\alpha + \eta N \bar{p})$  (and doing the same for the foreign country) yields a system of two equations that can be solved to derive  $N_E$  and  $N_E^*$ . For the home country, the number of entrants is:

$$N_E = \frac{4\delta(\kappa + 1)c_M^\kappa}{\eta(2 - v)(1 - \rho^*\rho)} \left[ \frac{(\alpha - c_D)}{(c_D)^{\kappa+1}} - \rho^* \frac{(\alpha - c_D^*)}{(c_D^*)^{\kappa+1}} \right]. \quad (54)$$

Substituting (54) into (53) then gives the total mass of firms operating in the home country:

$$N = \frac{4\delta(\kappa + 1)(c_D)^\kappa \left\{ \frac{\frac{(\alpha - c_D)}{(c_D)^{\kappa+1}} - \rho^* \frac{(\alpha - c_D^*)}{(c_D^*)^{\kappa+1}}}{(2 - v)} + \frac{\rho^* \left[ \frac{(\alpha - c_D^*)}{(c_D^*)^{\kappa+1}} - \rho \frac{(\alpha - c_D)}{(c_D)^{\kappa+1}} \right]}{(2 - v^*)} \right\}}{\eta(1 - \rho\rho^*)}.$$

Finally, the mass of home producers selling in the domestic market and that of domestic firms exporting to the foreign country are given respectively by:

$$N_D = G(c_D)N_E = \left(\frac{c_D}{c_M}\right)^\kappa N_E \text{ and } N_X = G(c_X)N_E = \left(\frac{c_X}{c_M}\right)^\kappa N_E. \quad (55)$$

Recalling that  $c_D = c_X^* \tau^*$ , it is clear from (54) that for  $N_E > 0$  to hold,  $c_X^* < c_D^*$  must also hold (and  $c_X < c_D$ ).<sup>22</sup> Hence, as in the non-union case considered by Melitz and Ottaviano [27], the minimum efficiency required to export is higher than that required to operate in the domestic market alone. Thus, only a subset of relatively more productive firms (with  $c \leq c_X$ ) will select themselves into an exporting status. All other firms with  $c_X < c \leq c_D$  will produce for the domestic market only.

The following proposition summarises the effects of union power on the market structure variables derived above.

**Proposition 5** *When the two countries are symmetric, an increase in the bargaining power of unions in one country: (i) reduces the mass of firms entering that country; (ii) reduces the mass of firms exporting from that country; (iii) increases the mass of domestic firms selling in the country – provided that the preference for variety is sufficiently strong.*

Imposing symmetry on (54), we find that  $\frac{\partial N_E}{\partial v} < 0$ . It then follows that  $\frac{\partial N_X}{\partial v} < 0$ . Thus, an increase in union power in a country will always reduce the mass of entrants into that country and the mass of exporters from that country. Substituting (54) into (55), however, we find:

$$N_D = \frac{4\delta(k+1)}{\eta(2-v)(1+\rho)} \frac{(\alpha - c_D)}{c_D}$$

from which it is clear that  $\frac{\partial N_D}{\partial v} > 0$  provided that  $\alpha > \frac{(2+\kappa)}{\kappa} c_D$ . So, if the preference for variety is sufficiently strong, more powerful unions result in a larger mass of domestic firms surviving in the domestic market. Hence, despite the fact that an increase in  $v$  reduces the mass of entrants into the industry, the total mass of domestic firms serving the home market can increase. This is due to the competition-softening effect that stronger unions have on the domestic market, making it easier for domestic firms to survive in the industry by increasing  $c_D$ .

To summarize: the opening up of trade does not alter qualitatively the effects of unionization on the productivity cut-off for firms producing only for the domestic market – as in autarky, an increase in the bargaining power of unions will result in more entry of less efficient firms, thus lowering the average industry productivity. However, an increase in unions' power will have an opposite effect on the cut-off of exporting firms, raising the minimum efficiency required to export and hence the average efficiency of exporters. Interestingly, the nature of these results does not depend on the level of market integration. However, at a maximum level of integration, under free-trade, the domestic and export cut-off points would coincide and hence the nature of the effect of unions power

<sup>22</sup>The expressions for  $c_D$  and  $c_X$  in (49) and (50) imply that for  $c_X < c_D$  the following condition needs to be satisfied  $\frac{L^*}{L} > \rho^{1+\frac{2}{\kappa}} \left[ \frac{1-\tilde{v}^2 \rho^*}{\tilde{v}^2 - \rho} \right]$ , where  $\frac{2-v^*}{2-v} = \tilde{v}$  defines a measure of the relative bargaining power of domestic unions.

on the equilibrium distribution of firms' productivity would correspond to that obtained in the closed economy.

### 3.2.2 Wages, incomes and welfare

As is clear from (47), more productive firms pay higher wages in equilibrium in both their domestic and export profit centres. However, given that  $c_X < c_D$ , it is also the case that the *domestic* wage of an exporting firm with cost parameter  $c$  is higher than its *export* wage: i.e.  $w_D(c) > w_X(c)$  always holds.

**Proposition 6** *Even though more productive firms pay higher wages than less productive ones in both domestic and export profit centres, within an exporting firm, the 'export-wage' is lower than the 'domestic-wage'.*

Due to market segmentation, an exporting firm faces different competitive pressures in its domestic and export market – as is evident from (34). When countries are symmetric, a firm's price elasticity of demand is unambiguously higher in its export than in its domestic market, i.e.:  $|\epsilon_{Dq}(c)| < |\epsilon_{Xq}(c)|$ . To see this, note that under symmetry  $p_{\max} = p_{\max}^*$  and  $c_D = c_D^*$ . Then, given that  $c_X = \frac{c_D^*}{\tau}$ , it is evident that  $p_X(c) > p_D(c)$  holds for any value of  $c$ ; this implies:  $|\epsilon_{Dq}(c)| = [(p_{\max}/p_D(c)) - 1]^{-1} < |\epsilon_{Xq}(c)| = [(p_{\max}^*/p_X(c)) - 1]^{-1}$ . More generally, for the non-symmetric case,  $p_X(c) > p_D(c)$  and thus  $|\epsilon_{Dq}(c)| < |\epsilon_{Xq}(c)|$  will hold if  $c > \frac{(v+2)(c_D - \tau c_X)}{(\tau-1)(2-v)}$ . Thus, firms' monopoly power is lower in their export market. Also, note that for the general case of asymmetric countries, the wage elasticity of labour demand for export facing the union is higher than in the domestic market:  $|\epsilon_{l_X,w}| = \left( \frac{2}{2-v} \frac{c}{c_X - c} + \frac{v}{2-v} \right) > |\epsilon_{l_D,w}| = \left( \frac{2}{2-v} \frac{c}{c_D - c} + \frac{v}{2-v} \right)$ , since  $c_X < c_D$ . Thus, by internalising the firm's lower monopoly power in its foreign market and the trade-off that exists between wage and employment, unions have an incentive to moderate their export wage demands in order to aid their firm's access to its foreign market.<sup>23</sup> Profit-centre level negotiations then result in 'wage-discrimination' across the different activities of the firm. The wages  $w_D(c)$  and  $w_X(c)$  are plotted in Figure 2 as a function of the labour input requirement  $c$ . It is evident from the figure that whilst within an exporting firm  $w_D(c) > w_X(c)$ , firms producing only for the domestic market, with  $c \in (c_X, c_D]$ , pay on average lower wages than exporters.<sup>24</sup> However, the export wage for the marginal exporters can be lower than the (domestic) wage paid by the more efficient non-exporting firms – thus enabling a relatively low productivity exporter to compete internationally. This result is in line with that obtained by Andersen and Sorensen [3] who, in a Ricardian trade model with heterogeneous firms, show that “wages are lower in firms that marginally manage to

<sup>23</sup>This result is similar to that obtained in an oligopoly setting by Bastos and Kreickemeier [6] who find that, for sufficiently high levels of international economic integration, unions moderate wage demands to aid the internationalisation of firms.

<sup>24</sup>These curves have been obtained for symmetric countries. The wages are plotted only for values of  $c$  for which firms are active, i.e.  $c \in [0, c_X]$  and  $c \in [0, c_D]$  for exporting and non-exporting firms, respectively.

export compared to firms marginally maintaining a position as nontradables".<sup>25</sup>

Insert Figure 2 about here

With firm-level bargaining, a firm pays the same wage to all its workers, regardless of whether they are employed in the production for export or for the domestic market. The cut-off points and equilibrium wage under firm level bargaining (for the monopoly union case, i.e. with  $v = 1$ , and for symmetric countries) are derived in the Appendix. The wages obtained with this bargaining regime are plotted together with those obtained under profit-centre level negotiations over the distribution of  $c$  in Figure 3 below.

Insert Figure 3 about here

The curve for the firm-level (unique) wage paid by exporters terminates at  $c = c_X$  where the wage curve for domestic-only firms starts. As these two curves illustrate, even with firm level wage setting, the wage of the more efficient domestic-only firms can exceed that of the least efficient exporters. Moreover, as expected, we find that  $w_X(c) < w_U(c) < w_D(c)$ . By internalising the lower monopoly power its firm has abroad, a union will have an incentive to set the unique wage under firm-level bargaining,  $w_U(c)$ , below that it would set for the firm's domestic market operation under the profit-centre level regime. However, a union will now have a lower incentive to moderate wage demands to aid its firm's international competitiveness – thus setting  $w_U(c)$  above the wage it would demand for the export market under profit-centre level bargaining. The adverse impact of this higher wage on the firm's competitiveness, in turn, implies that the minimum productivity required to export is higher under the firm-level regime than under the profit-centre one (i.e. the export cut-off level falls as wage setting shifts from the profit-centre to the firm level).

In a sense, unions' preparedness to accept decentralisation of wage bargaining at the sub-firm level can be interpreted as reflecting their willingness to moderate rent *extraction* in activities exposed to more intense product market competition in favour of rent *creation*, by protecting employment in those activities.<sup>26</sup> Our model suggests, however, that by enabling a closer link between wages and the differential competitive pressure and profitability a firm faces in its different markets, profit-centre level bargaining may ultimately allow unions to extract a higher *total rent* than that obtained with firm-level negotiations. This is evidently the case with monopoly unions, as shown in Figure A.2 in the Appendix that plots the total labour rents in the two regimes over the distribution of  $c$ .<sup>27</sup>

<sup>25</sup> As they point out, Naylor [30] also showed that unions in a right-to-manage model may be prepared to trade-off a wage reduction for employment gains from a foreign market.

<sup>26</sup> In a model in which unions can choose the amount of resources dedicated to rent extraction and rent creation, Aidt and Sena [1] demonstrate that they devote more resources to the latter in firms that are exposed to more intense market competition.

<sup>27</sup> Given their objective function, unions in this model would prefer profit-centre level negotiations. Clearly, were wage inequality to enter their objective function, the two regimes would present unions with a trade-off between wage dispersion and total labour rent.

In light of the tendency towards higher degrees of decentralisation of wage bargaining, down to the level of plants, our analysis also suggests that trade liberalisation can affect wage inequality even among homogenous workers within an industry along two dimensions: across firms (via its effects on competitive selection) and within firms (via wage discrimination across destination markets).

**Proposition 7** *A trade liberalisation that eases access to foreign markets reduces intra-firm and increases industry-wide wage dispersion.*

As far as intra-firm wage dispersion is concerned, a bilateral and symmetric trade liberalisation or a process of unilateral liberalisation by the foreign country (i.e. an increase in  $\rho$ , that makes it easier to export for home country firms), by reducing the discrepancy between a firm's price elasticity of demand in the two markets will shrink the difference between 'domestic' and 'export' wages and lead to a fall in the domestic cut-off  $c_D$  and an increase in the export cut-off  $c_X$ .<sup>28</sup> Therefore, whilst – for a given degree of trade openness – profit centre level negotiations result in within-firm wage inequality, increasing economic integration – by narrowing the gap in the competitive pressure felt by firms in their different markets – reduce the incentives for wage discrimination within the firm. However, intra-industry wage dispersion (measured by the variance of wages within the industry) increases in response to a trade liberalisation that reduces the cost of foreign market penetration. To see this, we first determine the average industry wage, given by:

$$\bar{w} = \left[ 1 + \frac{v}{2(\kappa - 1)} \right] \left\{ 1 + \left[ \frac{L \rho^{\frac{\kappa+2}{\kappa}} \left[ (2-v)^2 - (2-v^*)^2 \rho^* \right]}{L^* \left[ (2-v^*)^2 - (2-v)^2 \rho \right]} \right]^{\frac{\kappa}{\kappa+2}} \right\} \quad (56)$$

which, with symmetric countries, becomes:

$$\bar{w} = \left[ 1 + \frac{v}{2(\kappa - 1)} \right] (1 + \rho) \quad (57)$$

As is clear from (56) a bilateral and a unilateral increase in  $\rho$  always increases  $\bar{w}$ . Making use of (57), the variance of wages in the monopolistic sector in the case of symmetric countries can be derived as:

$$\sigma_w^2 = (\rho + 1) \frac{\left[ v^2 \kappa + \rho^2 (\kappa - 2) (v + 2\kappa - 2)^2 \right]}{4(\kappa - 1)^2 (\kappa - 2)}$$

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<sup>28</sup>Instead, a process of unilateral liberalisation by the home country (i.e. an increase in  $\rho^*$ , that makes it easier for foreign firms to access the home country's market) will have opposite effects on both cut-offs and wages. The effects of both bilateral and unilateral liberalisation on the cut-offs are the same qualitatively as in Melitz and Ottaviano [27]. Clearly, however, trade liberalisation has a different impact on wages and on the distribution of income in our model due to the presence of unions. These effects of trade liberalisation on wages are also consistent with those obtained (both theoretically and empirically), by Amiti and Davis [2].

which is clearly increasing in  $\rho$ . This result reflects the process of competitive selection within the industry triggered by trade liberalisation. On the one hand, the fall in  $c_D$  which implies the exit of the least efficient firms in the industry that pay the lowest wages, will work towards a reduction of wage dispersion. On the other hand, the redistribution of market shares towards the more efficient firms will increase wage inequality.<sup>29</sup>

Before concluding, we briefly turn to consider the effects of unionisation on welfare in the open economy. As in autarky, due to the absence of long-run profits, welfare in the economy corresponds to the indirect utility function, given by equation (29). For  $v = v^*$ , inspection of (32) reveals that  $B$  falls in  $v$  via the same type of effects described for the closed economy. As in the autarkic case, average welfare in the economy is then given by:

$$\bar{W} \equiv \frac{\sum W_\zeta}{L} = \frac{(\bar{VC} - \bar{l})N_D}{L} + 1 + \bar{q}_0 + B,$$

where the first term in brackets on the right-hand-side is average income and where  $\bar{VC}$  and  $\bar{l}$  are now given respectively by:

$$\bar{VC} = \frac{(2-v)(\kappa+v)}{4\delta(\kappa+1)(\kappa+2)(c_D)^\kappa} \left[ L(c_D)^{\kappa+2} + \rho L^* (c_D^*)^{\kappa+2} \right]$$

and:

$$\bar{l} = \frac{(2-v)\kappa}{4\delta(\kappa+1)(\kappa+2)(c_D)^\kappa} \left[ (c_D)^{\kappa+2} L + (c_D^*)^{\kappa+2} \rho L^* \right].$$

When the two countries are symmetric, these become respectively:

$$\bar{VC} = \frac{(2-v)(\kappa+v)L}{4\delta(\kappa+1)(\kappa+2)} (1+\rho)(c_D)^2,$$

and

$$\bar{l} = \frac{(2-v)\kappa L(1+\rho)}{4\delta(\kappa+1)(\kappa+2)} (c_D)^2,$$

which in turn imply that average income<sup>30</sup> is the same as in autarky:

$$\bar{I} = \frac{v}{\eta} \frac{c_D}{\kappa+2} (\alpha - c_D) + 1.$$

Analysis of these expressions reveal that the opening up of trade between two symmetric countries does not qualitatively alter the effects of changes in union power on welfare. Clearly, since the domestic cut-off  $c_D$  in the open economy is smaller than in autarky, the threshold level of  $\alpha$  at which positive welfare

<sup>29</sup>This result is in line with that obtained by Egger and Kreickemeier [14], who measure wage dispersion as the ratio of the average to the lowest wage in the industry (i.e. the wage of the marginal firms). Since, in our case  $w_D = w_X = 1$ , this measure in our paper would correspond to the average wage  $\bar{w}$  – which, as discussed above – is also increasing in  $\rho$ .

<sup>30</sup>Clearly, in a two sector economy, income is not solely determined by wages in the monopolistic sector since households also work in the lower wage homogenous good sector. Thus, average income depends also on the distribution of employment across the two sectors.

effects of an increase in  $v$  occur is also lower than in autarky. The effects of trade liberalisation on welfare are also dependent on the size of  $\alpha$ :  $\frac{\partial \bar{W}}{\partial \rho} \geq 0$  if, and only if,  $\alpha \geq \frac{2c_D[2(\kappa+1)-3v]}{(4\kappa-3v+6)}$ . Thus, when the preference for variety is sufficiently strong, trade liberalisation increases welfare despite the fact that in this instance it may reduce average income (since  $\bar{I}$  falls in  $\rho$  if  $\alpha > 2c_D$ ).

## 4 Conclusions

We have examined the effects of the interplay between labour market unionisation and international trade on competitive selection among heterogeneous firms. Though some of our findings echo those of other recent work in this area, this paper adds to the existing literature in important respects and generates interesting empirically testable predictions.

The endogenous determination of wages via bargaining between heterogeneous firms and firm specific unions in the presence of firm specific markups implies that equilibrium wages differ between firms – and thus between ex-ante identical workers. This result hinges on the role of unionisation as a rent-sharing mechanism between workers and firms. Additionally, decentralisation of bargaining at the profit-centre level results in two firm-specific wages related to production for the domestic and export markets, respectively. We show that whilst both wages are always higher in high productivity firms than in low productivity ones, *within a firm*, the *export* wage is lower than the *domestic* wage. This is because sub-firm level agreements result in a stronger link between wage demands and the different degrees of market power that firms have in their domestic and export markets – with unions being prepared to moderate rent extraction in those activities that are exposed to more intense product market competition. By protecting employment in the export profit centre of the firm, we show that this behaviour can in turn result in a higher total labour rent being extracted than under firm level negotiations.

These findings suggest that the nature of bargaining is an important channel through which trade liberalisation affects wage inequality. To the extent that operating in different markets exposes a firm to different competitive pressures, the observed tendency to adopt profit-centre level agreements can result in an additional source of wage dispersion. A testable prediction of the model is thus that, for a given level of openness, decentralisation of bargaining at the sub-firm level ought to result in exporting firms exhibiting higher intra-firm wage dispersion. Clearly, empirical research is required to investigate the extent to which changes in wage dispersion as a result of trade liberalisation occur across (as an eminently competitive selection effect) or within (as a wage discrimination effect) firms.

We identify three main channels through which an increase in the bargaining power of unions affects the nature of the industry equilibrium, namely: (i) a *variety effect*, (ii) a *counter competitive effect*, and (iii) a *selection effect*. These stem from the fact that, for a given bargaining power, a union's rent extraction ability is higher the higher is the productivity of the firm with which it

negotiates. As a result, a given increase in union power will translate in relatively larger wage demand increases in relatively more efficient firms – i.e. it will raise the cost of labour in more efficient firms proportionally more than in less efficient ones. In a two country setting – in which, as is standard in this literature, only the more efficient firms become exporters – an increase in unions’ bargaining power pushes up the minimum productivity required to export. Thus, a higher bargaining power of unions in one country can be thought of as (i) *softening* the competition facing domestic firms (with more firms of a lower efficiency entering the domestic market) and (ii) *toughening* the competition in the export sector (by increasing the level of efficiency required to become exporters). More generally, firms exporting to a country with stronger unions will face a softer competition from domestic firms in that market; instead, domestic firms in a market will face a tougher competition from exporters located in a country with more powerful unions. Thus, a key testable prediction of the model is that industries in countries where unions are stronger should be expected to have a lower average productivity – resulting in higher average markups and prices and in lower average quantities and profits – but also offer an easier access to foreign exporters.

## References

- [1] Aidt, T. S., and V. Sena, (2005). "Unions: Rent Creators or Extractors?", *Scandinavian Journal of Economics*, 107(1), 103-121.
- [2] Amiti, M. and D.R. Davis, (2011). "Trade, Firms and Wages: Theory and Evidence", *Review of Economic Studies*, forthcoming.
- [3] Andersen, T. M., and A. Sorensen, (2008). "Product Market Integration and Heterogeneity - Rent Sharing and Pricing to Market", *Review of International Economics*, vol. 16, No. 2, pp. 268–284.
- [4] Autor, D. H., L. F. Katz, and M. S. Kearney, (2008). "Trends in U.S. Wage Inequality: Revising the Revisionists", *Review of Economics and Statistics*, 90 (2), 300–323.
- [5] Barth, E., and C. Lucifora, (2006). "Wage Dispersion, Markets and Institutions: The Effects of the Boom in Education and the Wage Structure", IZA Discussion Paper 2181.
- [6] Bastos P. and U. Kreckemeier, (2009). "Unions, Competition and International Trade in General Equilibrium", *Journal of International Economics*, 79, 238–247.
- [7] Brown, B., (1987). *The Structure and Processes of Pay Determination in the Private Sector 1980-1986*, CBI, London.



- [8] Coşar, A. K., N.Guner, and J. Tybout, (2010). "Firm Dynamics, Job Turnover, and Wage Distributions in an Open Economy", NBER Working Paper No. 16326.
- [9] Davis, D., and J. Harrigan, (2011). "Good Jobs, Bad Jobs, and Trade Liberalisation", *Journal of International Economics*, 84, 26–36.
- [10] Del Gatto, M., G. Mion, and G. Ottaviano, (2007). "Trade Integration, Firm Selection and the Costs of Non-Europe", CEPR Discussion Paper No. 5730.
- [11] Driffill, J., (2006). "The Centralization of Wage Bargaining Revisited: What Have we Learnt?", *Journal of Common Market Studies*, vol. 44 no 4, 731-756.
- [12] Dustmann, C., J. Ludsteck, and U. Schönberg, (2009). "Revisiting the German Wage Structure", *Quarterly Journal of Economics*, 124 (2), 843–881.
- [13] Eckel, C., and H. Egger, (2009). "Wage Bargaining and International Firms", *Journal of International Economics*, vol. 77, pp. 206–214.
- [14] Egger, H., and U. Kreickemeier, (2009). "Firm Heterogeneity and Labour Market Effects of Trade Liberalization", *International Economic Review*, vol. 50 (2009), pp. 187-216.
- [15] Felbermayr, G., J. Prat and H.-J. Schmerer, (2008). "Globalization and Labor Market Outcomes: Wage Bargaining, Search Frictions, and Firm Heterogeneity", IZA working paper No. 3363.
- [16] Goos, M. and A. Manning, (2007). "Lousy and Lovely Jobs: The Rising Polarization of Work in Britain", *Review of Economics and Statistics*, 89 (1), 118–133.
- [17] Helpman, E., (2006). "Trade, FDI, and the Organization of Firms", *Journal of Economic Literature*, Vol. XLIV (September), pp. 589–630.
- [18] Helpman, E., and O. Itskhoki, (2010). "Labour Market Rigidities, Trade and Unemployment", *Review of Economic Studies*, 77, Issue 3, 1100–1137.
- [19] Helpman, E., O. Itskhoki, and S. Redding, (2010). "Inequality and Unemployment in a Global Economy", *Econometrica*, 78 (4), 1239-1283.
- [20] Jackson, J.P., (2006). *Changing the Bargain: The Stability and Change of Centralised Wage Bargaining in Open Liberal Economies*, PhD Dissertation, Cornell University.
- [21] Jürgens U., (2008). "Globalization and Employment Relations in the German Auto Industry." in *Globalization and Employment Relations in the Auto Assembly Industry: A Study of Seven Countries*, Ed. R. Blanpain, Kluwer Law International BV, The Netherlands.

- [22] Kamakura, Y., (2006). "Recent Issues Regarding Collective Bargaining and Conditions of Work in the Chemical Industry", Working Paper, International Labour Office, Geneva.
- [23] Leopold, J. and M. Jackson, (2001). "Decentralisation of Collective Bargaining: A Case Study", *Industrial Relation Journal*, 185-193.
- [24] Mayer, T. , and G. Ottaviano, (2007). "The Happy Few: The Internationalisation of European Firms", BRUEGEL Blueprint Series, Volume III.
- [25] McCall, L., (2000). "Explaining Levels of Within-Group Wage Inequality in U.S. Labor Markets", *Demography*, 37(4):415-30.
- [26] Melitz, M., (2003). "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity", *Econometrica*, vol. 71, No. 6, pp. 1695-1725.
- [27] Melitz, M., and G. Ottaviano, (2008). "Market Size, Trade, and Productivity", *Review of Economic Studies*, vol. 75, pp. 295–316.
- [28] Menezes-Filho, N.A., M.-A. Muendler, and G. Ramey, (2008). "The Structure of Worker Compensation in Brasil, with a Comparison to France and the United States", *Review of Economic and Statistics*, 90, 324-346.
- [29] Montagna, C., (2001). "Efficiency Gaps, Love of Variety and International Trade", *Economica*, vol. 68, pp. 27–44.
- [30] Naylor, R., (2000). "Trade and Wages When the Trade Regime is Determined Endogenously", *Review of International Economics*, vol. 8, pp. 556–65.
- [31] OECD, (1994). "Collective Bargaining: Levels and Coverage", in *Employment Outlook* (Paris, OECD), pp. 167-208.
- [32] OECD, (1997). "Economic Performance and the Structure of Collective Bargaining", in *Employment Outlook* (Paris, OECD), pp. 63-92.
- [33] OECD, (2004). "Wage-Setting Institutions and Outcomes", in *Employment Outlook* (Paris, OECD), pp. 127-181.
- [34] Redding, S.J., (2010). "Theories of Heterogeneous Firms and Trade", Working Paper 16562, NBER.
- [35] Schank, T., C. Schnabel, and J. Wagner (2007). "Do exporters really pay higher wages? First evidence from German linked employer-employee data", *Journal of International Economics*, 72 (1), 52–74.
- [36] Tuman, J. P., (2003). *Reshaping the North American Automobile industry: Restructuring, Corporatism and Union Democracy in Mexico*, Routledge, New York.

- [37] Visser, J., (2006). "Union Membership", *Monthly Labour Review*, January, 38-49.
- [38] Wälde, K., and P. Weiß, (2007). "International Competition, Downsizing and Wage Inequality", *Journal of International Economics*, 73, 396-406.

## Appendix – Wage and cut-offs for the case of firm-level bargaining

When wages are set with firm-level negotiations, each exporting firm will have one wage. In the case of monopoly unions (i.e. with  $v = 1$ ), the firm-level wage rule of a firm producing for both domestic and export markets (i.e. with  $0 < c < c_X$ ) is given by equation (40). When countries are symmetric this becomes:

$$w_U(c) = \frac{1}{3} + \frac{2}{3c} \frac{p_D(c) + \tau p_X(c)}{1 + \tau^2} \quad (58)$$

For the marginal firms producing only for the domestic market, the wage is given by equation (37). It is immediate to see that at  $c = c_D$ ,  $w_D(c_D) = 1$ . These firms also have zero operating profits, which implies:  $p_D(c_D) = w_U(c_D)c_D = c_D$ .

Let us consider firms that operate on both markets, i.e. with  $0 < c < c_X$ . From the inverse demand functions for marginal and infra-marginal firms and the profit maximising output,  $q_D(c) = \frac{L}{\delta} [p_D(c) - w_U(c)c]$ , we obtain:

$$c_D - p_D(c) = p_D(c) - w_U(c)c. \quad (59)$$

Their profit maximising export price will be:

$$p_X(c) = \frac{\tau w_U(c)}{2} c + \frac{P\eta + \alpha\delta}{2(\delta + N\eta)}. \quad (60)$$

Equations (58), (59), (60) give a system of three equations that can be solved to determine  $p_D(c)$ ,  $p_X(c)$ , and  $w_U(c)$ , respectively given by:

$$\begin{aligned} p_D(c) &= \frac{\tau(P\eta + \alpha\delta)}{4(\delta + N\eta)(\tau^2 + 1)} + \frac{c_D(2\tau^2 + 3)}{4(\tau^2 + 1)} + \frac{c}{4} \\ p_X(c) &= \frac{(3\tau^2 + 2)(P\eta + \alpha\delta)}{4(\delta + N\eta)(\tau^2 + 1)} + \frac{\tau c_D}{4(\tau^2 + 1)} + \frac{1}{4}\tau c \\ w_U(c) &= \frac{\tau(P\eta + \alpha\delta)}{2c(\delta + N\eta)(\tau^2 + 1)} + \frac{c_D}{2c(\tau^2 + 1)} + \frac{1}{2} \end{aligned} \quad (61)$$

Noting that (42) implies that when countries are symmetric

$$c_X = \frac{c_D}{\tau w_U(c_X)} \quad (62)$$

we can rewrite  $w_U(c_X)$  in (61) as follows:

$$w_U(c_X) = \frac{(\delta + N\eta)(\tau^2 + 1)c_D}{(\delta + N\eta)(2\tau^2 - \tau + 2)c_D - \tau^2(P\eta + \alpha\delta)} \quad (63)$$

Following the same procedure used to obtain (59), we know that  $p_X(c_X) = \tau w_U(c_X)c_X = \frac{\tau c_D w_U(c_X)}{\tau w_U(c_X)} = c_D$ , from which the export price of the marginal exporters (whose export quantity is zero) is:

$$p_X(c_X) = c_D \quad (64)$$

Noting that  $p_X(c_X) - p_X(c) = p_X(c) - \tau w_U(c)c$  and making use of (64) we then obtain  $p_X(c) = \frac{\tau c}{4} + \frac{(\tau+2\tau^2+2)c_D}{4(\tau^2+1)} + \frac{\tau^2(P\eta+\alpha\delta)}{4(\delta+N\eta)(\tau^2+1)}$ . Equating this to the expression for  $p_X(c)$  in (61), we can solve for  $z \equiv \frac{P\eta+\alpha\delta}{\delta+N\eta}$  to obtain:

$$z = c_D \quad (65)$$

Making use of (65), the wages in (61) and (63) can now be rewritten as:

$$\begin{aligned} w_U(c) &= \frac{1}{2} \left( \frac{c_D}{c} \frac{\tau+1}{\tau^2+1} + 1 \right) \\ w_U(c_X) &= \frac{\tau^2+1}{\tau^2-\tau+2} \end{aligned} \quad (66)$$

Thus, as in the profit-level bargaining case, more productive firms pay higher wages. It is also clear from (66) that  $w_U(c_X) > 1$  for  $\tau > 1$  and  $w_U(c_X) = 1$  for  $\tau = 1$ .

Given that with firm-level bargaining, firms producing for the domestic market will have different wage rules depending on whether they are also exporters or not, the zero-expected-profit free-entry condition is written as follows:

$$\int_0^{c_X} \pi_D^x(c) \frac{\kappa c^{\kappa-1}}{c_M^\kappa} dc + \int_{c_X}^{c_D} \pi_D^d(c) \frac{\kappa c^{\kappa-1}}{c_M^\kappa} dc + \int_0^{c_X} \pi_X^x(c) \frac{\kappa c^{\kappa-1}}{c_M^\kappa} dc = f_E$$

where the superscripts  $d$  and  $x$  refer to the domestic-only or exporting status of the firm. In particular, given the expression for  $w_U(c)$  in (66), and noting that  $w_U(c_X)$  in (66) implies that from (62):  $c_D = \tau c_X \frac{\tau^2+1}{\tau^2-\tau+2}$ , the profits from domestic sales and from exports of firms with  $c < c_X$  will be respectively:

$$\pi_D^x(c) = \frac{1}{16} \frac{L \left[ \tau c_X \left( \frac{2\tau^2-\tau+1}{\tau^2-\tau+2} \right) - c \right]^2}{\delta},$$

$$\pi_X^x(c) = \frac{1}{16} \frac{L}{\delta} \tau^3 (c_X - c)^2.$$

Profits of firms that only produce for the domestic market, with  $c_X < c < c_D$ , will instead be:

$$\pi_D^d(c) = \frac{1}{16} \frac{L}{\delta} (c_D - c)^2.$$

The expected zero-profit free-entry condition can then be solved to derive  $c_D$ :

$$c_D = \frac{\tau(\tau^2+1)}{\tau^2-\tau+2} \left( \frac{16f_E\delta c_M^\kappa}{\kappa L D} \right)^{\frac{1}{\kappa+2}}$$

$$\text{where } D = \frac{\tau^2 \left[ 2 \left( \frac{\tau+\tau^3}{-\tau+\tau^2+2} \right)^\kappa (\tau^2+1)^2 + (3\tau^2+4)(\tau-1)^2 \kappa^2 + (\tau-1)(10\tau-7\tau^2+9\tau^3-8)\kappa + 2\tau(-\tau+\tau^2+\tau^3+\tau^4+2) \right]}{\kappa(-\tau+\tau^2+2)^2(\kappa+2)(\kappa+1)},$$

from which  $c_X$  can be obtained from  $c_D = \tau c_X \frac{\tau^2+1}{\tau^2-\tau+2}$ . Figure A.1 below plots the cut-off in the two bargaining regimes against  $\tau$ .

The total labour rent a union can extract from an exporting firm in the two bargaining regimes can be obtained by substituting the expressions for the equilibrium wages and a firm's employment levels into:  $V_U(c) = (w_U(c) - 1)(l_D(c) + l_X(c))$  and  $V_S(c) = (w_D(c) - 1)l_D(c) + (w_X(c) - 1)l_X(c)$ , which give a union's total labour rent for the firm-level and profit centre level case, respectively. These are plotted in Figure A.2 below.

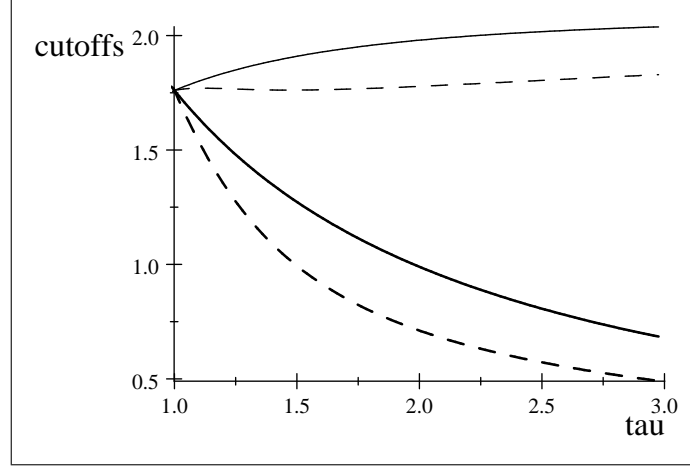


Figure A.1. Cut-offs for firm-level and profit centre-level bargaining  
Profit-centre level bargaining (solid lines):  $c_D$  (thin),  $c_X$  (thick)  
Firm-level bargaining (dashed lines):  $c_D$  (thin) and  $c_X$  (thick)

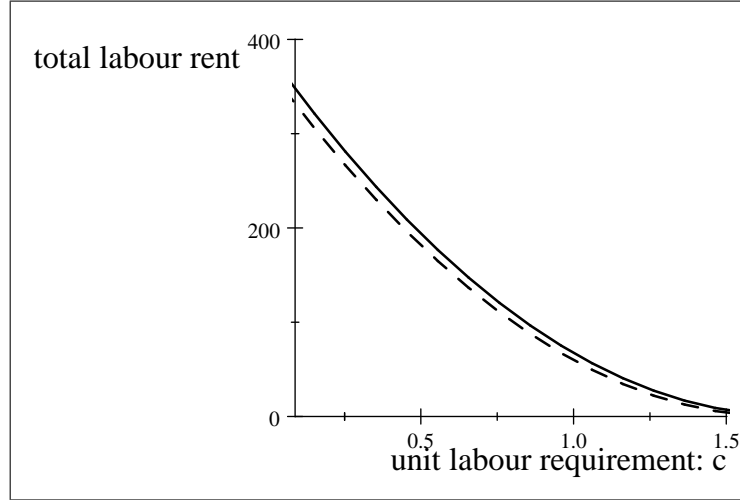


Figure A.2. Total labour rent  
Profit-centre level bargaining (solid line), firm-level (dashed line)  
 $v = 1$ ,  $\kappa = 2$ ,  $\delta = 0.2$ ,  $\eta = 6$ ,  $c_M = 10$ ,  $L = 100$ ,  $f_E = 1$ ,  $\tau = 1.118$

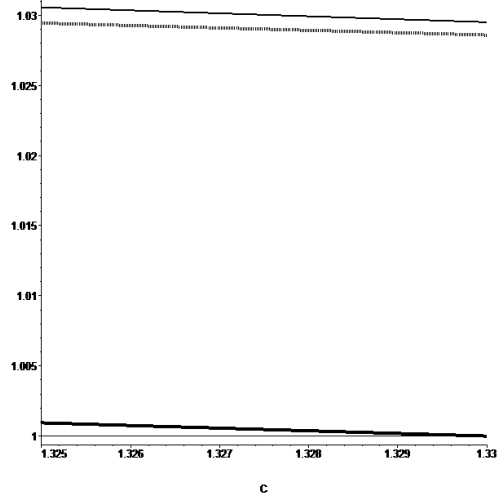


Figure 1. Optimal wage rules:  $w_D(c)$  (thin line),  $w_X(c)$  (thick line),  $w_U(c)$  (dotted line)  
 $v = 0.5$ ,  $\tau = 1.118$   
 Cut-off levels:  $c_D = 1.487$  and  $c_X = 1.33$

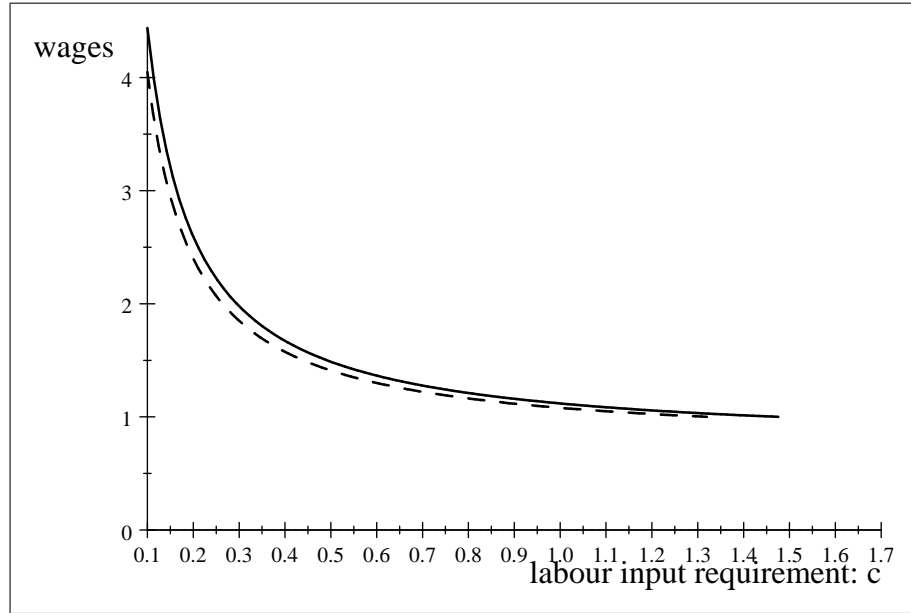


Figure 2. Profit-centre level wages:  $w_D(c)$  (continuous line) and  $w_X(c)$  (dashed line)  
 $v = 0.5$ ,  $\kappa = 2$ ,  $\delta = 0.2$ ,  $\eta = 6$ ,  $c_M = 10$ ,  $L = 100$ ,  $f_E = 1$ ,  $\tau = 1.118$   
 Cut-off levels at these values:  $c_D = 1.4756$  and  $c_X = 1.3199$

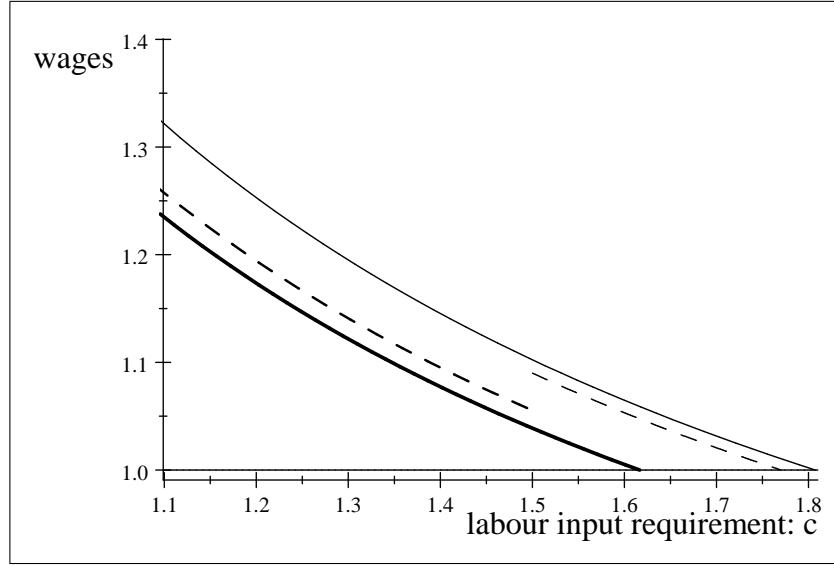


Figure 3. Wages

Profit-centre level bargaining (solid lines):  $w_D(c)$  (thin),  $w_X(c)$  (thick)

Firm level bargaining (dashed lines):  $w_{U,D}(c)$  (thin)  $w_U(c)$  (thick);

Cut-off levels for profit-centre bargaining:  $c_D=1.8072$  and  $c_X=1.6165$

Cut-off levels for the firm-level bargaining:  $c_D=1.7701$  and  $c_X=1.5002$

$v=1$ ,  $\kappa=2$ ,  $\delta=0.2$ ,  $\eta=6$ ,  $c_M=10$ ,  $L=100$ ,  $f_E=1$ ,  $\tau=1.118$